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ERRATUM

In the introduction to the article on page 169, Bordeaux should be described as being in south-west France — not south-east.

SOIL RESOURCES OF THE WORLD

by **G. V. Jacks,** *Commonwealth Bureau of Soils.*

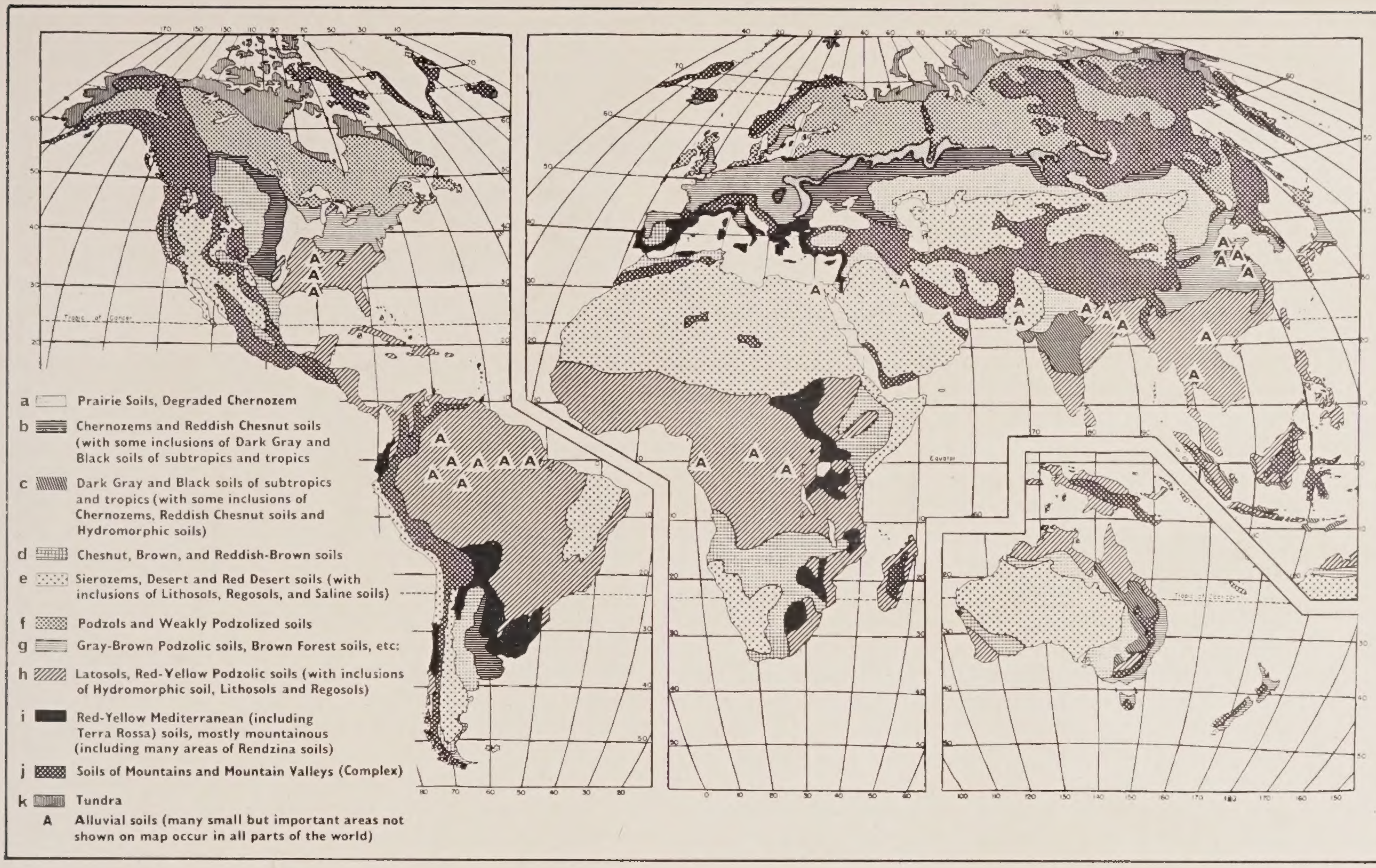
One of the most tremendous events in the history of life occurred about 100 years ago when man acquired the power to make soil fertility. Until then green plants, with a little help from the weathering of rocks, had been the only makers of fertility. They did it by using solar energy to convert air and water into plant material which was consumed by animals and micro-organisms which made humus which provided nutrients and improved living conditions for plants. That is a grossly over-simplified description of a very complex cycle, but it represents the only way in which soil fertility had been made since life first appeared. All that farming men had been able to do was to improve the efficiency of the cycle by irrigation (providing water to enable plants to do their job), by such means as using the surplus manure made by grazing animals to feed arable crops, and growing nitrogen-fixing legumes, and applying lime and occasionally saltpetre. How best to use and maintain the fertility accumulated during thousands of years of plant growth was the farmer's chief concern with his soil.

Now all that is changing. Soil fertility—by which I mean the capacity of soil to support life—is being increased by human action far above the levels to which any plants could have raised it. This is being done primarily by the use of manufactured fertilisers, but *agricultural* fertility is also being increased by breeding high-yielding crop varieties, by the use of pesticides to destroy crop competitors, and by the use of mechanical power for cultivation, drainage and irrigation. This rapidly growing capacity of man to raise the fertility of almost any soil to hitherto undreamed-of heights is a matter of the profoundest biological significance when we consider either the future of mankind as a whole, or merely the soil resources of the world. The factors which limit the capacity of man to make soil fertility are mainly economic.

It is now widely recognised that if—and it is a big if—adequate means were available for making fertility, the soils of the world could easily support any global population that is likely to arise within the next few centuries. With the recognition of the potentialities of man-made soil fertility, it is being realised that whether or not soil is made productive depends far more on the effective demand for its produce and on market accessibility than on the inherent fertility of the soil. For example, the chemically richest soils in the world are the black steppe soils (chernozems) of Russia, but the crop yields obtained from them are very much lower than from the originally much poorer former forest soils of western Europe, where farmers can afford to apply vast quantities of fertilisers because they have rich and populous markets at their doorstep. The chernozems occur in semi-arid regions and do not get enough water to produce high yields. To irrigate the soils would be very expensive, and the demand for the extra produce that could be obtained is not high enough to justify the cost. But, other things being equal, those soils which are naturally fertile will cost less to maintain in economically farmable condition than infertile soils. Natural soil fertility is still a factor of great importance in countries which have inadequate other developed resources with which to buy man-made fertility.

The distribution of the main soil types of the world is shown on the accompanying map. Soils are formed by the action of living organisms on weathered rock particles, and the nature of both the kind of life that arises and the kind of weathering depends on the climate, so soils can be regarded as the result of a combination of climatic, geological and biological influences. The soil types shown on the map thus represent types of geographical environment; each type carries a more or less characteristic natural vegetation, and is suitable for certain kinds of agriculture or other uses by man.

Perhaps the most striking feature of the map is the vast area occupied by desert (*e*), mountain (*j*) and tundra (*k*) soils. These areas, which account for about half the total land area, can be ruled out as unusable in the foreseeable future; they are too dry, too inaccessible or too cold, though high production can be and is got from certain desert areas by irrigation. Indeed, the most long-cultivated soils in the world, in Egypt, are desert soils made and kept fertile by irrigation. Most of the easily irrigable desert and semi-desert areas have already been brought under irrigation, but advances in water engineering are greatly



Soil map of the world (reproduced, by permission of FAO, from Efficient Use of Fertilisers *[Rome, 1958]).*

extending the possibilities of irrigation into areas of potentially high productivity.

USABLE TEMPERATE SOILS

The most intensively used soils are the grey-brown podzolic or brown forest soils (*g*) which occur in the densely populated regions of western Europe, eastern North America, and northern China and Japan. These soils were originally covered by deciduous forest, and in their natural state would be regarded as of only moderate fertility, but at the present time, as a result of man's continued activities, they represent the most productive soil type in the world. They are the soils to which the type of living association known as western European civilisation has adapted itself. The lowest-yielding of the brown—forest—soil areas shown on the map is in China, a country which is not rich enough to make soil fertility.

The soils of Europe reached a state of lowest fertility in human use about the fourteenth century since when fertility has increased steadily with the progressive industrialisation and enrichment of the region. But when agricultural systems similar to the European have been applied to other types of soil in other parts of the world the results have been very different and sometimes disastrous. It has been estimated that about 3 per cent. of the earth's land surface is covered by brown forest and allied soils, and most of it is utilised for intensive agriculture.

A more widely distributed soil type is the podzol (*f*), which stretches in a broad belt across the north of North America and Eurasia and is occupied mainly by coniferous forests which in thousands of years of undisputed occupation have made this soil, which is remarkably well adapted for conifers. The podzol is a very acid, chemically impoverished soil which men have succeeded, at great labour and expense, in converting to productive agricultural use, as in Scotland and Scandinavia, but it has mostly been left in forest. With proper silvicultural management, which is only just starting, the podzol area should be able to provide the world indefinitely with all the softwoods it requires. Podzols occupy about 10 per cent. of the land surface.

Chernozems, Prairie and Chestnut Soils

The chernozems (*b*) and related prairie soils (*a*) are the black earths of natural semi-arid and sub-humid grasslands. In their natural state they seem to be the ideal soils for agriculture—chemically rich, with a good crumb structure, porous, yet able to hold water and deliver it to plants. Their principal areas are in south Russia and Siberia, central North America and Argentina. Adjoining them and elsewhere (Australia, Africa) on the map will be seen areas of chestnut soils (*d*) (so-called after their colour) which occur in drier climates, and are naturally covered by dry-steppe vegetation. The areas of these soil groups constitute the 'bread baskets' of the world. They are used for extensive cereal production and ranching. Fertility declines rather rapidly when they are cropped, the soils lose their good structure and become very liable to erosion. The grassland soils, with their great natural fertility, though lacking adequate moisture, provide an excellent illustration

of how new systems of cultivation must be adjusted to new soil conditions.

The reason why the black earths, so rich and so easy to cultivate, have only recently been fully utilised by man has been their inaccessibility in the interior of continents before roads and railways were built. They are now a tremendous potential source of additional agricultural production for the future when means of maintaining their fertility have been discovered—as almost certainly they will be. Already methods have been devised for controlling soil erosion and the more efficient utilisation and conservation of the limited moisture supply, cropping is being diversified and higher-yielding, drought-resistant crops are being produced. Yields, by European standards, on these soils are at present rather low because water rather than plant nutrients is the limiting factor, but the soils, particularly the black humus-rich chernozems and prairie soils, seem to be the ones next destined to benefit from man's fertility-making powers.

It is estimated that chernozems and prairie soils occupy about 5 per cent., and chestnut soils about 7 per cent. of the total land area.

The area (*i*) marked black on the map, around the northern littoral of the Mediterranean, is occupied by red and yellow soils—terra rossa—on which the civilisations of Greece and Rome flourished and waned. This once fertile area is now highly eroded. With the means now available the soils could be remade, but the operation would be extremely costly, and in the eroded areas might involve a period under forest, for which the land could not be spared, before it again became agriculturally productive.

TROPICAL SOILS

The humid and semi-humid tropics undoubtedly represent our biggest untapped soil resource. The soils of the tropics are variable, but they have not been studied and classified nearly as closely as temperate soils, and for present purposes we can distinguish just two contrasting types of tropical soils—the red soils or latosols (*h*) and the black soils or black cotton soils (*c*), so-called because they were first observed and studied in India where they have been used for cotton-growing.

Latosols

The latosols embrace a number of different soil types with the common property of a red or reddish colour indicative of intense weathering and leaching. Natural vegetation varies from dense rain forest to dry savanna, but even rain-forest soils, covered with luxuriant natural vegetation, are of little use for producing agricultural crops because all the plant nutrients in them are continuously circulating between the forest and the soil, and when the forest is cleared for cultivation any nutrients remaining in the soil are rapidly washed out. Latosols are generally very poor in plant nutrients, especially nitrogen which is essential for protein production, and there are few tropical peoples who can afford to apply fertilisers which are at present applied mainly to high-priced plantation crops. At present no system of permanent agriculture, unless highly capitalised, has been devised for latosols. The traditional, indigenous agricultural system is shifting cultivation, in which land is cleared and cropped for one to three years and is then abandoned to return to forest or bush for 10-20 years. As populations have increased in many tropical countries the period of the bush fallow has been shortened with consequent intensified soil exhaustion and sometimes erosion.

It has been said that the tropics have everything (warmth, sunshine and usually water) in abundance for plant growth, except plant food. This, like all such sayings, is only partly true. In any case, the fertilisers used on temperate soils are not so well adapted to tropical latosols because latosols have low absorbing capacity and fertilisers are liable to be leached out before crops can get them. Perhaps even more important, tropical food-producers are seldom wealthy enough to buy them. Since climate, which man cannot yet control, is so favourable to plant growth, tropical soils would seem to be the ideal medium for treatment with man-made fertility. But we do not yet know how to apply the treatment except at a price which few tropical countries can afford. We are, however, learning to conserve the fertility that is still there, with the resources available. To increase that fertility will be a future step.

Latosols and related soils occupy about 15 per cent. of the land surface. The areas marked A on the map are areas where alluvial soils, recently deposited by river floods, are common. The fertility of these varies with the nature of the deposited material; many are more than usually fertile.

Black Cotton Soils

The black cotton soils (*c*) are of quite small extent except in India. They are very heavy, usually deep soils whose colour belies their humus content, which is very low. They are 'self-swallowing'—that is, they crack in the dry season and the topsoil falls into the cracks so that there is continuous circulation of soil material. This constant renewal of topsoil has enabled some Indian soils to be cultivated for centuries, but they are of low inherent fertility and have bad physical structure. They are, however, promising material for applying modern methods of cultivation, drainage and fertilising.

Paddy Soils

The man-made soils on which paddy rice is grown under water are not indicated on the map. These are the greatest food source of the tropics and sub-tropics. Paddy-rice growing is the only well established system of permanent tropical agriculture. The world contains some 300 million acres, producing some 300 million tons of paddy rice. But yields vary from $2\frac{1}{2}$ tons per acre in Japan and Australia to half a ton in India. If India could afford to apply man-made fertility to her paddy soils on the same scale as is done on the much smaller areas of Japan and Australia there would be no shortage of food in India. People do not get enough to eat because they cannot afford the food, and it is only because they cannot buy it that the food is not produced. There is no lack of potential fertility in the world's soils.

SOIL SURVEY AND LAND-USE PLANNING

by **H. Greene,** D.Sc., *Adviser on Tropical Soils*
Rothamsted Experimental Station.

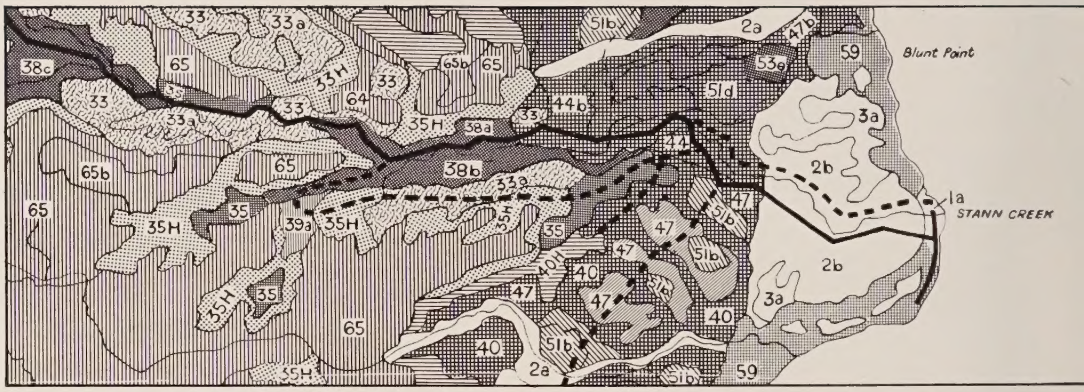
Success in agriculture depends in part on the industry and skill of the farmer, on economic circumstances and political stability, on good luck with weather and on control of pests. To an important degree success also depends on soil: if the seed falls on good soil it may yield a hundredfold. The success or failure of an individual farmer depends on soil, for this determines what kinds of crops he can grow, their yield, quality and timeliness and his chance of surviving unfavourable conditions of one kind or another. In countries with a long agricultural history these matters are well understood and their importance is weighed when considering farming prospects and other possible uses of land. In under-developed countries there may be no appropriate agricultural skill and there may be severely restricted choice in methods of land use. A wrong choice may involve heavy financial loss and much human misery.

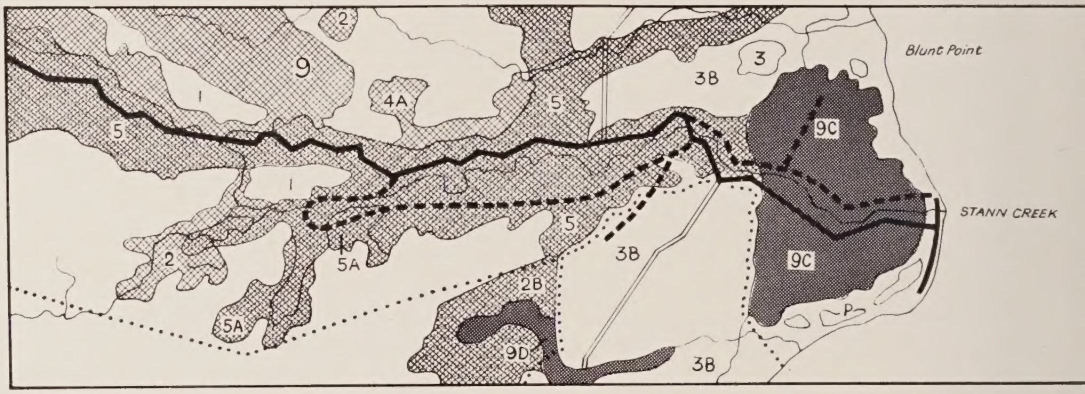
The risk of running into these disasters can be reduced by spending time and money to find out (a) what kinds of soil occur (soil classification); (b) where they occur (soil survey); and (c) how they can best be used (agricultural experimentation). The answers will be found more quickly and at less cost if the work is done by men well trained in the appropriate skills. It is a part of the skill to assess what degree of detail or what broadness of generalisation is required for a particular situation at a particular time.

Soil Classification

Brief inspection of a region may show that it contains hilly areas of which part may be suited for some tree crop, more level areas apparently suited for cultivation, and swamps of which part may be suited for rice. In such a region topography is a guide to soil classification. In another region, changes in vegetation depending on rainfall or other climatic factor may serve as a guide to the distribution of soils and possibilities of development.

In a third region a geological factor may be decisive; where, for example, there is a rather bare quartzite ridge or luxuriant vegetation on deposits of volcanic ash. All these and other features may be economically studied, first in aerial photographs and then in the field where pits and borings permit examination of the soil in depth. This work constitutes a preliminary assessment: in a region of a few hundred square miles some 10 or 20 soils may be readily distinguished and may account for almost the whole area. Of the different soils, some may be considered to offer





Examples of soil and land-use mapping. Above, part of the British Honduras provisional soil map, and below, the same area shown on a potential land-use map (both scale 1/250,000). The soil map shows: 1a, coastal sand; 53, 53c, 53d, infertile coast deposits; 59, peaty coastal sand; 2a, 2b, 3a, 38a, 38b, 38c, 44b, 50, 51d, alluvial soils; 33, 33a, 35, 35H, 35a, 39a, 40, 40H, 47, 51b, acid soils on non-calcareous rocks; 65, skeletal soils on non-calcareous rocks. Recommended uses shown on the land-use map are: 1, protection forest; 2B, mahogany forest; 3, 3B, pine forest; 4A, cacao; 5, 5A, citrus; 9C, leys with swamp rice; 9D, leys with plantain, banana, ground food; P, *problem soil.*

(Maps reproduced from *Land in British Honduras*, by permission of the Controller of H.M. Stationery Office, London. Crown Copyright reserved.)

promise for one crop and others for another. This kind of differentiation can be made by any active intelligent farmer; it results in a local classification of soils and a sensible working plan. It is an excellent first step in agricultural development. Its weakness lies in its purely local basis: soils differentiated in the region have no ascertained or presumed relation with those of another region and so it is difficult to make use of information obtained elsewhere.

Accordingly the next step in soil classification is to move some way towards a system that applies to a far wider region—for example, to the tropics or to the world as a whole. Names such as Tropical Red Earth (local types A, B, C) or Black Cotton Soil (local types P, Q, R) have the important implication that the same kind of soil occurs in different places, is the result of fairly uniform processes and has somewhat familiar properties under cultivation. Progress in this direction demands specialised training or wide experience and is limited by the present lack of an agreed world-wide system of classification. There are, however, many less comprehensive systems, any one of which is better than none.

Chemical analysis is not an acceptable substitute for classification based on examination of soil and landscape in the field. To collect representative samples of soil demands technical knowledge that few people have: at best there is doubt whether the material tipped on to a laboratory bench has any close relation to the natural soil explored by plant roots, teeming with living creatures, penetrated more or less freely by water and air. It is this natural soil that is to be classified and mapped. Routine analytical tests can indeed be helpful but their interpretation is sometimes obscure except where there is a long record of experience with a particular district and crop. Where such experience is lacking, laboratory analyses are best used to supplement field observations on soils and crops.

Soil Survey

Soil survey aims at the making of a map and preferably at the publication of a map plus explanatory booklet for sale to the public. A map is a very concise means of presenting information. Soil maps show considerable variety in the kind of information they present: geological structure is prominent in some; topography and drainage pattern in others. Native vegetation may be minutely traced where this happens to be closely aligned with the pattern of soils. Such a pattern may change quite abruptly into one dominated by geological features. Before the soil survey begins, it is necessary to decide upon the scale of the map to be produced. This will depend on the purpose for which the map is made and will determine the amount of detail that can conveniently or usefully be shown. For example, the proposed map may be at a scale of 1/50,000 based on field work with prints of aerial photographs at contact

scale of about 1/25,000 and, according to the purpose in mind, it may be useless to record any area smaller than 10 or even 100 acres.

The actual soil pattern is likely to be much more complex than can be shown on this scale, and therefore both the surveyor in the field and the cartographer in the drawing office have to develop skill or art in locating their boundaries. In some places wide areas are broadly uniform, though each little hill may have red soil and each little depression grey soil. Or the area may be broadly uniform with a fairly even but spotty distribution of salt patches. For such areas the minute detail is omitted and the mapping unit represents an association of soils which are separately described in an accompanying booklet. The detail can then, if necessary, be picked out in the field.

Maps at a much larger scale are sometimes provided in the form of enlarged aerial photographs for individual owners of land. These show far more surface detail, but the general pattern may be difficult to trace. Or, in contrast, to provide a bird's-eye view of a large region, it may be desired to produce a map at a small scale (e.g. 1/1 million) when much detail must be omitted and information must be more schematically presented. These various maps are to be considered as tools: a detailed map made to help the individual farmer; a semi-detailed map for wider technical use; a small-scale map for making broad decisions or for general education. For example, it is certainly of interest to know what kinds of soil occur in different parts of Africa, but a map of convenient size giving this information (in so far as it exists) is of no use to the individual African farmer. On the other hand the very detailed map that is of value to one farmer is useless to anyone distant more than a few miles from his particular holding.

Agricultural Experimentation

Without support of agricultural experimentation a soil map may be of limited value, even though it embodies erudite classification, scrupulous field observations and artistic cartography. In a developed country, the makers of the soil map are likely to be aware of current agricultural practice and are likely to make sure that their map is acceptable to the intelligent farmer by recognising features that are important to him. In under-developed countries, however, there may be an urgent need to produce for export crops that have not been tried there before—and there will be successive enquiries as one crop after another comes to mind. No one would wish to start the work afresh on each occasion and therefore, even though a soil survey arises from some specific request regarding, for instance, cocoa, it is economic to record for each area those relatively permanent features that may assist in answering future requests about, say, rice or rubber. Nevertheless, soil surveys are usually done hastily for some urgent purpose and are sure to need revision as opportunity arises.

It is commonly thought that a soil survey should include instructions about which crops to grow and how to grow them. Something of this sort is possible when there exists much information, as happens when many farmers are profitably growing the crop and do so without incurring soil erosion, provided precautions are taken. The Soil Conservation Service of the USDA has systematically made specific recommendations for land use in the light of such information, paying particular attention to steepness of slope as a danger signal. Their procedures, however, should not be followed in detail for crops and countries where the relevant information has not yet been obtained.

The soil survey may well lead to provisional recommendations about crops and land use, but these need to be checked by experiments efficient in design and well-conducted. In general these are factorial experiments comparing, for instance, different varieties of the crop, sown at different dates, with and without fertilisers, other cultural conditions being made as favourable as contemporary techniques permit.

Because of the need for close supervision such field experiments are usually restricted to a few readily accessible sites. A most valuable purpose is served by a wider scatter of less complex experiments which nevertheless are so devised that in the aggregate they provide valuable information both about the behaviour of the soil and about the growth of the crop. It may be found, for example, that soils distinguished in the survey behave much alike when used for sugar cane or, conversly, that differences in growth of cane show up some soil differences that were missed in the survey.

Land-use recommendations lacking experimental support are of doubtful validity, while those having such support are dated and, after 10 years or so, may require revision because economic conditions have changed or because new agricultural techniques have been devised. Thus, though maize was long regarded as an erosion-promoting crop, it can be grown safely in monoculture when closely sown on land that is well fertilised and where the soil surface is protected by trash from impact of raindrops.

WORLD'S SOILS TO BE MAPPED

A project to map the world's soils, which has recently been announced by FAO and UNESCO, should, it is claimed, provide a realistic picture of the distribution of major soils and lead to a broad outline of how different soil areas can best be used. The project is part of the Freedom from Hunger Campaign.

The first stage will be the preparation of regional maps—for Australia, it is stated, in 1962; for the American continent, Europe and the Near East in 1963; and for Asia and Africa in 1964.

The second stage will be the preparation of a draft of the world soil map in 1966, with a view to publication in 1968. It is expected that the final map will be in the form of a loose-leaf atlas of some 40 sheets.

The house cricket, Acheta domesticus, originally a common desert insect, became a serious pest in the irrigated areas of Pakistan.

INSECT HAZARDS IN LAND DEVELOPMENT

by **Sir Boris Uvarov,** K.C.M.G., D.Sc., F.R.S., *Anti-Locust Research Centre, London.*

In the present period, when the world is faced with a rapidly increasing gap between the production of food and other amenities of life and the requirements of growing human population, great hopes are placed on the expansion of cultivation, particularly in the newly developing countries. Such expansion involves radical changes in the ecology of the areas under development, including profound effects on insects, many of which are the main competitors with man for all kinds of produce of the land. What these effects are likely to be in any particular country, as a result of the envisaged system of land use, remains largely unknown, especially as regards tropical and subtropical countries, which are great potential producers.

However, this is not the first time in history that virgin lands, or lands previously exploited in a primitive manner, have been subjected to large scale development. It is, therefore, useful to see what effect the main types of land use have had in the past and to derive from such examples lessons for the future.

Clearance of Forests

The large areas of forest and scrub bordering on semi-arid and arid lands are regarded of great potential value for agriculture. Partial deforestation, followed by patchy shifting cultivation, is a common feature of primitive land use and its main general ecological effects are replacement of tree cover by grasses and herbs, and a change of the ecoclimate towards greater aridity. Land so cleared, cultivated for a short period and then abandoned, provides an opportunity for insects of more arid habitats to invade newly opened areas, and such adventive fauna includes many pests. Thus, deforested areas of north Borneo and the Philippines, overgrown with grasses, provided opportunities for the migratory locust to breed where it could not live before. Another example is offered by some species of tsetse flies which require a patchwork of secondary bush, in which they breed, and of grassland where grazing animals provide their food; such conditions are created by clearance of the original continuous forest. In the dry temperate lands of southern Europe, northern Africa, and western Asia wholesale destruction of forest and scrub created conditions exceptionally favourable for grasshoppers.

Grazing

Immoderate grazing in areas with deficient, or uncertain, rainfall leads to a replacement of uniform grass cover by a pattern of short grasses, small herbs and patches of bare soil. These are the ideal conditions for grasshoppers and the history of pioneer agriculture in the American west is

a tale of long-drawn-out battles against these pests. Nor is this war over, since the cost of crop losses from grasshopper in the United States in the 10-year period 1937-1949 averaged 10 million dollars per annum, in spite of well organised and costly control measures. In the vast grasslands of South America, over-grazing and degradation of pastures resulted in many native grasshoppers becoming pests, both of pastures and of crops. In the virgin lands of the Soviet Union, now undergoing extensive and accelerated development, grasshoppers and other insect pests are a serious and growing menace. The locust and grasshopper problems in Australia and South Africa are largely due to over-grazing of pastures.

Effects of grazing in hot arid lands are little known. Harvester termites in South Africa are beneficial to soil fertility in undisturbed grasslands, but when grass cover is reduced by over-grazing, they destroy the remaining grass and lead to land erosion. Such notorious pests as army-worms are essentially connected in their ecology with poor pasture grasses such as *Cynodon dactylon*, but the resulting moths undertake migrations and from time to time devastate both pastures and crops in Africa, as happened recently in Kenya.

Opening of Virgin Lands for Agriculture

In new areas being opened for agriculture the emphasis is usually on cereal crops. From an insect's point of view, this amounts to the replacement of wild grasses, on which they lived before, by more reliable, continuous and qualitatively better sources of food. It is a curious fact that even entomologists concerned with pests of grain crops usually study them only in the crops and only occasionally turn attention to their 'alternative wild host-plants', which, in fact, are the primary sources of infestation. Virgin grasslands are vast reservoirs of potential pests of cereals and their cultivation is accompanied by a dramatic reconstruction of the native pest fauna and its adjustment to the new situation. Detailed quantitative studies in the semi-arid south-east of the Soviet Union have shown that out of 312 species of insects found on virgin land only 135 were present in a new wheat field some two months after ploughing, but the mean density of insect population was nearly doubled. Further, although only some 20 species were abundant on wheat, they included most serious pests, such as flea-beetles, the number of which increased 20 times, and wheat thrips which became 360 times more numerous than on wild grasses. As with pastures, the agricultural development of Soviet virgin lands resulted in an alarming growth of danger from many pests, including grasshoppers.

Again, little is known of the consequences of cultivation in tropical grasslands. However, the introduction of large-scale mechanised cultivation of sorghum in the Sudan resulted in heavy losses from native grasshoppers, hitherto quite unsuspected as pests. It has to be borne in mind that the vast savannas of Africa have a rich specialised grass-feeding fauna, many members of which are ready to transfer their activities to grain crops. As it is, important pests of tall cereals, such as maize and sorghums, are stalk-borers (larvae of moths) which certainly belong to the native fauna of tall grasses. Sorghum midges, carriers of a serious sorghum virus disease, are also native.

Fallow and Abandoned Lands

Although some mention of abandoned lands has been made above, this problem deserves special attention, particularly because any expansion of native farming inevitably results in a high proportion of such lands, while large-scale mechanised agriculture involves areas under fallow.

In the Montana prairies several species of cutworms (larvae of Noctuid moths), which were regarded as rarities before settlement, became numerous on abandoned lands and are now outstanding crop pests.

The so-called Italian grasshopper, *Calliptamus italicus*, was a serious pest in southern Russia in the second half of the last century, when virgin lands in these areas first underwent rapid development; its outbreaks there diminished recently, but its importance is growing in the newly developing lands of Kazakhstan. Thorough ecological studies have shown that in the virgin steppe this grasshopper is confined to patches of sage-brush, *Artemisia*; when the land is first cultivated, crops are almost free of grasshoppers, but the abandoned land is colonised by sage-brush in four to five years and then becomes exceptionally favourable for the grasshopper. Severe infestations every four to five years appear to be connected with this course of plant succession on idle lands.

Grasshopper activities in the United States appear to be favoured by the 'soil-bank' policy, which encourages restricted cultivation, with a view to preventing over-production of grain and restoring the soil. This policy results in an increase of areas previously under cultivation, but now abandoned, where some grasshopper species particularly thrive.

What happens to the insect fauna of abandoned lands in sub-tropics and tropics is little known. However, recently cultivated and abandoned lands in the Sudan and Senegal proved to be amongst favourite egg-laying grounds of the desert locust, even in the areas where its swarms could not breed before the land was cleared from scrub and cultivated.

Irrigation

In most arid areas there are great hopes of increasing production by developing irrigation which results in drastic alterations in the ecoclimate, soil, vegetation and the insect fauna.

One of the most widely cultivated and profitable crops grown in irrigation is lucerne (alfalfa). In California, a pretty yellow butterfly, *Colias phylodice*, which occurred sparingly on native clovers, became a most serious pest of irrigated lucerne. Grasshoppers in Arizona and Argentina, where a long dry period normally makes it impossible for them to breed more than once a year, were enabled to produce several generations per annum owing to continuous humidity and abundant fresh food of lucerne fields. In the Soviet Middle Asia, losses up to 60 per cent. of lucerne seed from a variety of insects have been reported. Another

important irrigated crop is cotton. In the Sudan, some species of thrips, which have been unimportant pests of some riverine crops, are now causing regular damage to cotton of the vast Gezira irrigation scheme, where their survival during the long dry season is ensured by the presence of weeds on irrigated land.

A striking example of entomological effects of irrigation is that of the black-headed cricket in western Pakistan, which is no other than the well-known 'cricket on the hearth', *Acheta domesticus*. It is a species widely distributed in the deserts of north Africa, Arabia and south-western Asia, which has been introduced with merchandise into nearly all countries of the world. In its native deserts it lives in the areas with heavy clay soils, escaping heat and dryness by hiding in deep cracks and coming out only at night. In the past it has been only occasionally recorded as a minor pest, but when large irrigation schemes were developed in Pakistan some 30 years ago, the cricket rapidly became a serious pest of cotton, oil seeds and grain crops on irrigated lands.

While the insects already present on the spot are thus particularly favoured by irrigation, it also plays an important part in their further spread. The cucumber beetle, *Diabrotica balteata*, which formerly occurred in the south-eastern corner of California, in the last 40 years has spread over most of the state along the irrigation canals, which enabled it to cross stretches of desert where it could not possibly survive. Such artificial 'bridges' also helped in the spread of other important pests from Mexico into the southern United States.

A special problem, although not agricultural, is that irrigation canals and areas flooded by overflow of water from them provide new breeding places for mosquitoes and for diseases carrying molluscs. In Puerto Rico mortality from malaria in the cities surrounded by irrigated sugar cane plantations was nearly three times higher than where sugar cane was grown without irrigation. Even tsetse flies are known to find shade and humidity essential for their breeding in irrigated gardens in the areas of northern Nigeria where otherwise they could not exist.

A special case of irrigated agriculture is that of desert oases, where water is derived from deep wells. Ecological conditions in oases are utterly different from those in the surrounding desert and they are populated by a restricted insect fauna, many members of which are accidentally introduced from elsewhere with cultivated plants.

Tree Planting

Apart from the reclamation and reafforestation of previously denuded lands, there are unquestionable prospects of developing useful tree cover in some semi-arid areas naturally devoid of trees, by careful selection of suitable kinds of trees and their protection in the earlier stages of their establishment. Such artificial tree plantations, e.g., in Ukraine, soon become populated by special insect fauna, preserved in the remnants of forests in ravines and river valleys, and many of them add to the hazards of the establishment.

An ambitious project of forest shelter-belts, criss-crossing the steppes of southern Russia, had as its aim a general amelioration of ecoclimate, by the accumulation of water from melting snow, and by moderating the effects of drying winds. In view of the great importance attached to the project, attention was paid to studying all such effects, as well as the alterations in the plant cover and in the insect fauna of the areas between shelter-belts. As far as insects were concerned, the changes were profound. Many species, adapted to semi-arid conditions, tended to disappear, while there was an increase in more northern faunistic elements, including such notorious pests as the hessian fly, frit-fly, and cereal flea-beetles, which require more humid conditions. There was an important increase in the damage from grain bugs, *Eurygaster*, *Aelia*, which had been previously handicapped by scarcity of shelter required for their hibernation, but now had it provided for them in the immediate vicinity. While the general effect of shelter-belts was to increase the yield of grain crops, in many cases this gain was reduced and even nullified by greater losses from insect pests.

Main Lessons of the Past

This necessarily brief survey of the insect hazards in newly developing countries provides distressing evidence that many of the past efforts to increase resources needed by man served largely to benefit pests and ensured their persistence.

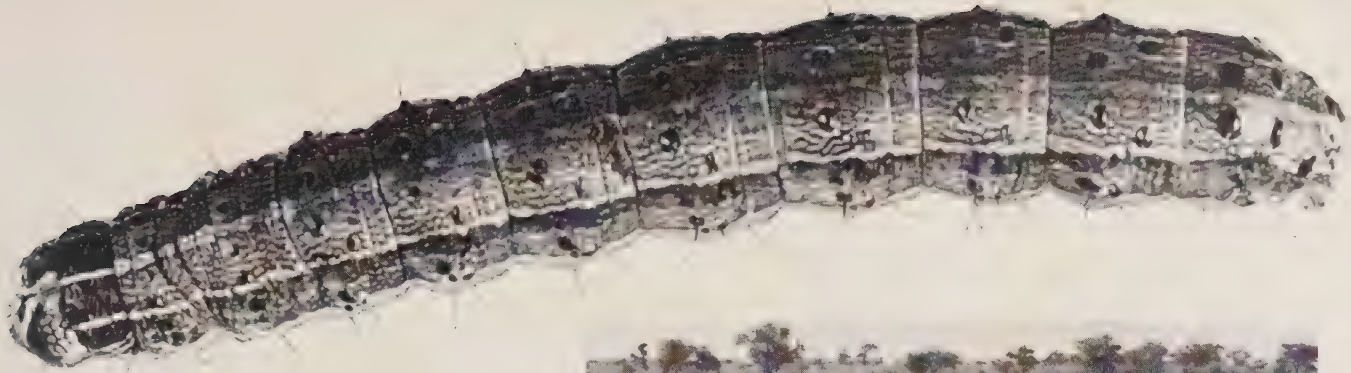
It needs particularly to be stressed that the greatest hazards often presented themselves during the initial stages of development, when ecological conditions underwent revolutionary changes, favouring the few insect species previously kept in check by not very suitable ecoclimate and insufficient food resources, but now able to benefit from the improved conditions. Any wild fauna is composed of a variety of insects with different ecological requirements, and there are always in it such elements that are able to take advantage of a change, while others go down. In this way, man introduces large scale selection experiments wherever he begins to exploit the land.

It is now reasonably clear, in the case of many insect pests, how it might have been possible to devise a system of land use which would not benefit them. Thus, a rigid control of grazing, before it deteriorated, could have kept grasshoppers in check; a crop rotation system can usually be devised to frustrate some pests, etc. In fact, the present agricultural, i.e. essentially ecological, methods of pest prevention are merely aiming at restoring the already disturbed balance.

It is, unfortunately, too easy and also useless to point out the past errors, some of which brought the damage beyond repair, and the object should be to learn from them and try to avoid them during the development of new countries.

Outlook

Vast plans for developing the resources of such regions as Africa, southern Asia and South America are being laid down, and many projects are actually being implemented. An entomologist cannot fail to notice that such plans are



The armyworm, Laphygma frugiperda, *a most serious pest of crops in South America, is an example of a migrant. Other related species in Africa are suspected to originate on over-grazed land.*

When the original dense scrub in semi-arid West Africa is cleared for shifting cultivation of millet, water-melons, etc., the land is made eminently suitable for breeding of the desert locust.

usually based on thorough surveys of the area to be developed as regards its climate, soils, vegetation, communications, labour, markets, etc., in fact everything except the insect hazards to the crops to be introduced. The only exception is, in some cases, a reference to the need for mosquito, or tsetse fly, control. The main reason for this is the not uncommon view that insect pests are invaders and their potential importance cannot be foreseen. Therefore, it is preferred to wait and see whether they appear as a serious hazard and then devise the means of controlling them; by that time the ecological upheaval has gone far enough to make the particular pest a dominant member of the fauna, requiring continuous expenditure on control. The latter, consisting essentially of wholesale application of insecticides on the crops themselves, is merely defence, eliminating the immediately menacing surplus of the insect's population, but leaving a large proportion of it to survive and to multiply for the next attack.

Even in the most advanced countries, where modern insecticides and machinery ensure a reasonable protection of crops from insects, there are no prospects of reducing the costs of control, which are increasing at an alarming rate. It has been recently calculated (1) that in India where annual crop losses from insects are estimated at £360 million, it should be possible to save a portion of crops worth £69 million by spending £7.3 million per annum on chemical control. The expenditure, even on that scale, would serve merely to reduce the annual losses by one-fifth and must be recurrent, its rate rising with the expanding production. Therefore, while it is correct to claim that chemical control of pests provides a reasonable return, the financial outlay necessary to achieve its general effectiveness can hardly be faced by any developing country.

The policy of first encouraging insect pests by development schemes which ignore them, then attempting to control them chemically can, in the long run, be of less benefit to the producing countries than to those with highly developed chemical industry, which need new and ever expanding markets for their exports.

On the other hand, it is possible to use lessons of the past, some of which have been outlined above. A policy aiming at prevention of insect pests in any particular country should begin with including in preliminary surveys studies of the native insect fauna, with the emphasis on the species associated with plants related to those intended for introduction. Their ecological study would reveal the probability of their adaptation to the new conditions and could influence the choice of crops not likely to suffer and of agricultural practices less favourable to the increase of pests.

In many of the older countries there have been developments which almost ruined the land and hard efforts are being made now to restore its productivity. Can one hope that the almost virgin lands of tropics and subtropics, from which so much can be expected, will be saved from similar fate? The general need for approaching the development of Africa as an ecological problem has been recently stressed (2), but even in that very comprehensive survey the hazards from insect pests received less attention than they deserve.

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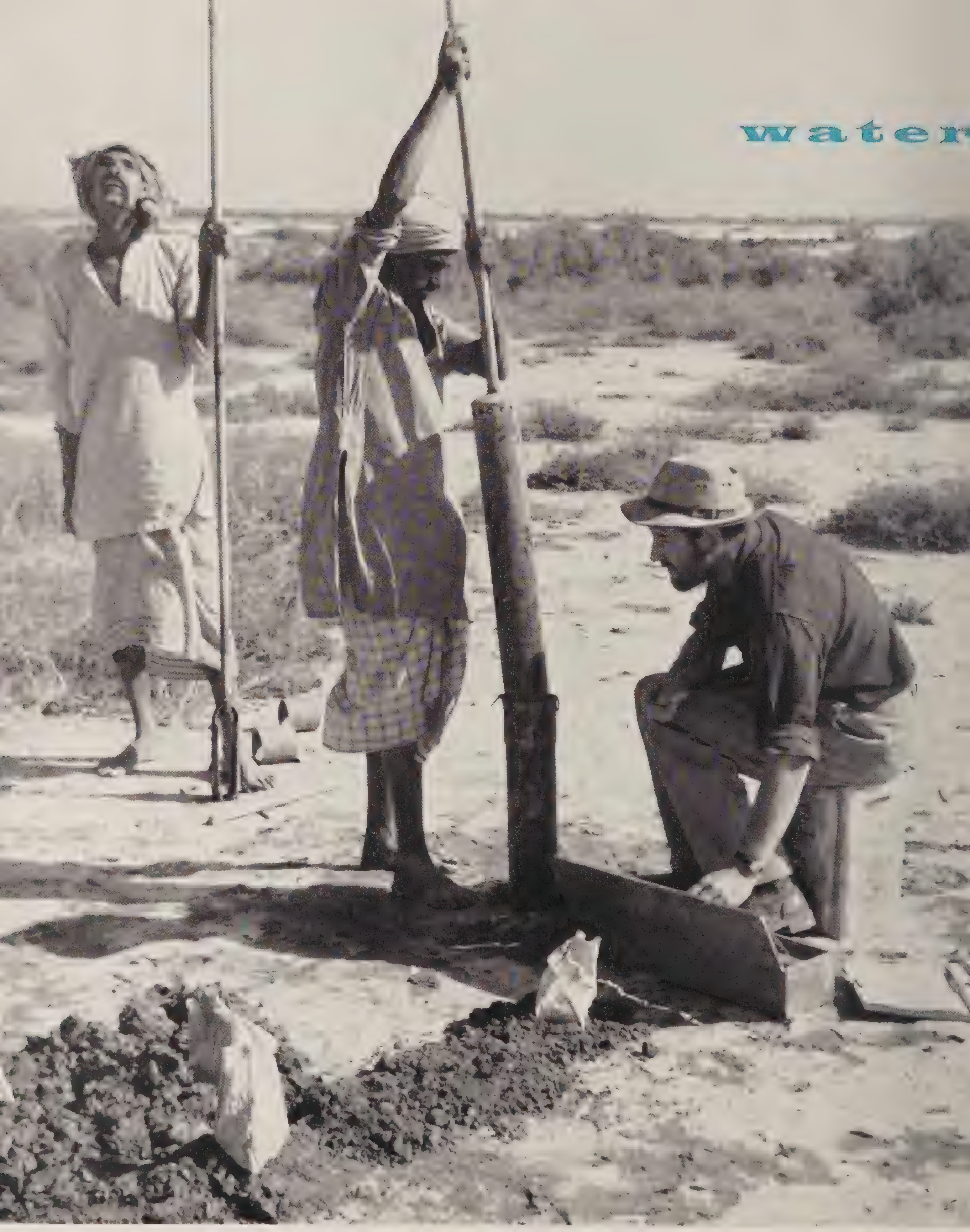
water



Preparing for a soil-permeability test. An auger hole has penetrated below the water-table and has been cased for support. Here water is being removed by 'bailer'; later the rate of recovery of the water level will be measured.

and soil a relationship important in agriculture

by **V. C. Robertson,** *Hunting Technical Services, Ltd.*

Outside the cool temperate and wet tropic zones there are vast areas of land where water is critical to agriculture. Rainfall may be, in annual total, sufficient for field crops; but its seasonal distribution may be uneven or unreliable and so become the main limiting factor to production. In arid or semi-arid regions total rainfall may be insufficient for the growing of crops by this means alone, so that agriculture must depend upon irrigation. Eventually, advances into cheaper production of fresh water from the sea (a process at present only economic in special cases for drinking-water supplies) and development of such techniques as cloud-seeding (which, however, are not of universal application) may provide vast resources of water for agriculture: but until this happens efficient use of limited supplies remains the keystone of agricultural improvement and development throughout much of the world.

The closest interaction between soil and water—and the greatest need for study of such effects—occurs in irrigation agriculture. Nevertheless, a good deal of attention is rightly being paid to such effects in 'dry' or rainfed farming—though probably not as much attention as there should be. Where rainfall is a limiting factor, it is especially important to see that water actually gets into the soil, where the crop can use it. Many soils in such areas, with low organic-matter content, suffer from poor structure generally and particularly poor or unstable crumb-structure. Under the impact of raindrops—and especially short-duration storms of very high intensity—such soils tend to produce an almost impervious surface, which reduces infiltration and increases run-off. This surface run-off, which should have penetrated into the soil for the benefit of crop plants, may become a major agent of erosion; so that the failure of the soil to absorb rain as it falls may actually lead to physical loss of the soil from the site. Uncontrolled run-off of this kind, of course, not only causes erosion *in situ* but may be the critical cause of serious floods as well as silting of reservoirs and irrigation works lower down the drainage basin.

Both surface 'capping'[1] and erosion caused by rapid surface run-off can be seen on the deep loessial soils of the Potwar Plateau in the northern part of West Pakistan. Here the traditional method for controlling the problem is construction of low earth walls (bunds) around fields, so that rainwater is contained within them long enough to soak into the soil. Provided the fields are properly levelled and the bunds well-maintained, with special provision for the removal of excess water from exceptional storms, this method works well enough. But if these conditions are not met—for example, if maintenance of field bunds is made difficult by the extensive activities of burrowing rats—surface waters breaking out from weakened bunds can accelerate erosion. Probably fuller use of broad-based terraces would be a major improvement in such areas, though here a non-technical problem arises, for small fragmented holdings make treatment of the land in large units difficult. Such socio-economic problems often loom large in agricultural improvement programmes, but they should not stand in the way of technical studies needed to develop a proper understanding of problems and their treatment.

Research in Nigeria

In Northern Nigeria, the Research Station at Samaru has a wide and enterprising programme of research. In the part of Nigeria in which Samaru is situated rain-fed cotton is an important crop. The yield of the crop has been limited by rainfall, and work to improve penetration of rain into the soil has yielded spectacular results. In 1959, a record crop of cotton (2,200lb. as against previous yields of 600lb.) was produced in a year of below-average rainfall—an impressive performance achieved by the introduction of tie-ridges (ridges put in at right-angles to those on which the cotton plants are grown normally, thus preventing surface run-off down the rows of plants). Similar effects were obtained by the use of surface mulches of residues from other crops, such as sorghum.

Where rainfall is not only limited in quantity but is also poorly distributed—for example, concentrated in a short wet season with a long rainless period—crop production may depend on storage of water during the season of relative plenty. In the arid parts of Kalat, in West Pakistan, an interesting traditional method is employed for storing water in the soil. In the upland valleys the staple food is wheat, as opposed to sorghums and millets in the lowlands. The wheat is grown in winter, but excess water occurs in summer, derived from the monsoon storms. A variation of the flood irrigation system known as 'sailaba' cultivation in this part of the world is used, summer floods being diverted on to bunded fields in July. The water soaks in and remains sufficient to grow a crop of wheat sown in November. Soils sampled by the author in November, when

[1]'Capping' is the development of an impervious layer at the soil surface.

A water-logged date garden in an irrigated area in Sind, West Pakistan.

Well managed field terraces with grassed bunds which effectively allow rain to infiltrate into the soil and control run-off (near Muzaffarabad, Kashmir).

wheat crops were newly germinated, were fully moist to a depth of six feet and more. The soils are themselves interesting, as they may be described as man-made alluvium, developed from years of flooding of the sailaba basins by silt-loaded water.

Another interesting traditional method of cropping on 'conserved' water occurs in the extreme north-east province of Northern Nigeria, Bornu, where shallow clay basins fill with water in the wet season and, as the water retreats, the drying margins are cropped with a quick-maturing sorghum. Similar practices are carried out in Somalia, where rivers such as the Wabi Shebelli fill depressions in their flood-plains during the rainy seasons. Rather than introduce entirely new methods, there are strong arguments in favour of developing these traditional practices, by better regulation of flood supplies, by weed control, by cultivation and with bunding equipment.

But it is with true irrigation that the fullest understanding of soil/water relationships is needed. The quality and quantity of irrigation water needs to be studied in relation to the soils available for use; water requirements of crops require assessment and trial; and surplus application may be needed to control salinity.

New Irrigation Schemes

Development of new irrigation schemes involves a radical change in land use, and it is vital to study the nature both of available soil and available water in order to assess the effects the one may have on the other and therefore their basic suitability for use under irrigation. Methods of land classification developed in the United States by the Bureau of Reclamation have become widely used in what are known as project feasibility studies. The system has its critics as well as its supporters. The number of 'capability classes' is limited – 6 – and it is difficult within the system to express differential classification in respect of individual crops. For example, land which is of first-class potential for groundnuts is not necessarily so for cotton or for rice. But notwithstanding such limitations, and the obvious need to modify what is basically an economic classification when it is applied outside its country of origin, the system is one which can be and is employed to advantage on many development projects. Soil factors used in assigning capability classes include fertility status, salt content (soil), texture, structure, density, porosity and depth. These, when related to slope measurements and field tests on permeability and infiltration, allow a realistic assessment to be made of the irrigable potential of the soils under study. (Many other factors are of course included in the full economic assessment.)

Water quality is a vital factor in the long-term success of irrigation. Most river waters, and groundwaters, contain

salts in solution. The long-continued application of such waters can result in the build-up of soil salinity, especially if there is no net movement of water down through the soil profile. It can also cause deterioration of soil structure. Soil salinity can also, of course, build up through upward movement of salts from shallow saline water-tables. This can be a comparatively rapid process, and its importance is stressed by Dr. Verhoeven in his article[2] on soil salinity in this issue of *Span*.

Few irrigation schemes without controlled drainage do not court the danger of salt build-up. One exceptional scheme is the Gezira cotton scheme in the Sudan, but this scheme has an outstanding factor in its favour—the quality of the Blue Nile water. The average salinity of the Nile at Cairo varies between 130 and 204 ppm, and such figures can be halved with confidence for the Blue Nile water used in the Gezira, as the Blue Nile drains a catchment composed largely of volcanic lavas and Archaean rocks. In contrast the Tigris, draining an area composed mainly of marine sediments, averages between 190 and 370 ppm of soluble salts, with figures certainly exceeding 500 ppm seasonally. The excellent quality of the Nile water, combined with rigid control of irrigation and the non-intensive crop rotation, has ensured the success of this still expanding scheme.

In assessing water quality and its effects on soil and on plant growth, it is of course necessary to know what salts are present as well as the total amount. The system most widely adopted for such assessment is again one developed in the United States, by the Department of Agriculture's Salinity Laboratory in California. Waters are classified in terms of total salinity and of 'sodium hazard'—as expressed by the Sodium Absorption Ratio (S.A.R.) which is itself an expression of the balance between sodium and calcium ions in solution. High concentrations of sodium, of course, directly affect plant growth, and application of high 'sodium-hazard' waters may cause development of sodium clays, with consequent deterioration of soil structure, as described by Dr. Verhoeven.

Damage to soil structure following long-continued irrigation is, however, a problem which may stem from other causes not yet clearly understood. Such development is common in Iraq, culminating in very dense soils of extremely poor structure. Extensive analyses have shown that there is no constant simple relationship between their poor structure and 'adsorbed' sodium. Extreme forms of these soils have a hummocky surface—a soil phenomenon first described in Australia as 'gilgai'. These 'gilgai' soils are now virtually useless for agriculture and have been found (in Iraq) only in areas presently irrigated or showing evidence of irrigation in the past. Both on the ground, and from the air, their surface pattern is extremely distinctive, so that they can be readily distinguished if not so readily explained. But the subject is an important one which calls for more research—deteriorated soil structure and increased soil density are undoubtedly inhibiting factors to crop growth, and the condition is widespread in the irrigated or irrigable areas of Iraq. On these poorly structured soils tiny patches of vigorous crop growth, which were found to be related to ants' nests, give an indication of the controlling effect of soil density (the ants bring in organic matter and the area of their activity results in a notably more friable and open soil).

[2]See pages 162-165—Ed.

Rising Water-tables

Rising water-tables present grave problems in irrigation development, and in West Pakistan this problem is one of national importance. The solution of the problem lies in controlling the level of groundwater at a depth which will neither cause anaerobic conditions in the root zone of crops, nor allow upward movements of salts from saline groundwater by capillary movement.

Control of a water-table can be achieved by pumping from deep or shallow wells; by a system of open or tile drains which intercept the water-table; or by a combination of both. Close attention to suitable crops and crop systems, accurate assessment and careful control of water application, and the introduction of tree plantations with a high rate of transpiration, may all contribute towards effective and economic control of the water-table. But soil studies remain fundamental, with special emphasis on field studies of permeability and infiltration, which are necessary in design and spacing of drains and in assessing 'drainability'.

Where tubewell drainage is a possibility [a tubewell is a metal casing, perforated for part of its length and inserted in a deep bore-hole packed with gravel which acts as a filter] exploration of the deep subsoil is essential, sometimes to a depth of 500 ft. or more. The economics of tubewell drainage is a fairly complex subject, but very broadly it may be said to depend on 'transmissibility' of the aquifer —i.e., the ease with which water can be withdrawn from or can move through the water-bearing medium—and the salinity of the water which is being tapped. The former determines the spacing of the wells; the latter determines the methods of disposal of the pumped water, ranging from immediate reuse for irrigation in the case of good quality waters, to the necessity for complete removal from the area in the case of highly saline waters.

This article has done no more than touch on some of the more fundamental aspects of the soil/water relationships as they affect agriculture in areas where water supply is critical. It is encouraging to see the increasing attention being paid to these problems, which are basic to agricultural improvement.

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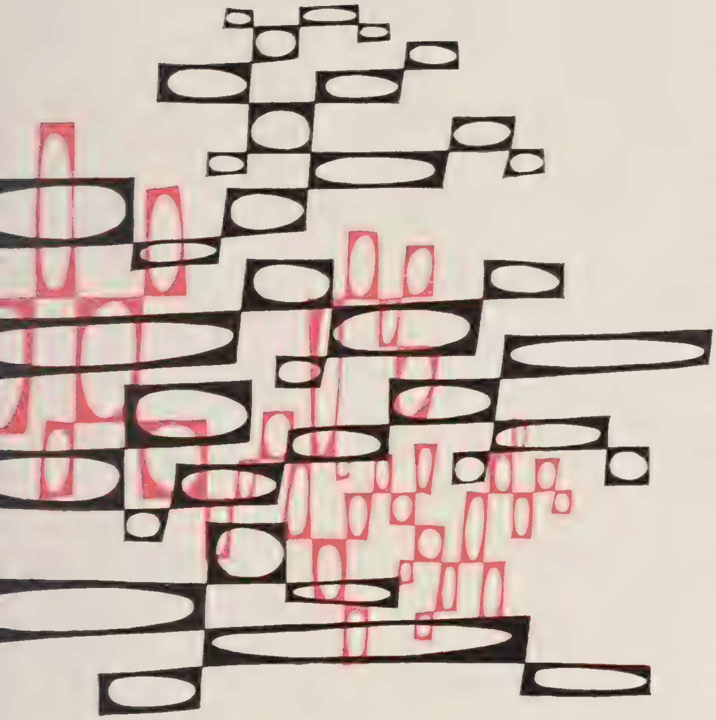
Soil salinity — a world-wide problem

Accumulations of salt in the soil, the condition known as soil salinity, are caused by water movement. When rain falls on a soil part of it runs off the surface, part wets the soil, and if the rain is heavy enough part will drain down through the soil to the water-table. When the storm ceases the water in the soil is lost partly by evaporation from the surface and partly by transpiration through the plants growing in it. Transpiration ceases when the remaining water is too strongly held by the soil for it to be utilised by the plant.

However, in a soil predisposed to salinity the groundwater level remains so superficial that the water lost by evaporation from the surface is continually replaced by capillary suction from below. If these waters are saline, salts will be deposited at the surface as the water evaporates. High groundwater levels occur in particular along the bottoms of slopes, in river valleys and in other depressions.

In these lower parts of the landscape evapotranspiration (the combined effect of evaporation from the soil and transpiration through plants) never ceases completely, and large quantities of water are vaporised, their salts—often hardly absorbed by the plants—remaining in the soil. Often, even in arid regions, the salt content of the groundwater (mainly originating from the weathering of minerals) is not excessively high, but the accumulation of salts caused by continued evapotranspiration may impede crop growth and may also change the properties of the soil.

The lower the rainfall and the higher the water-table, the more pronounced is the salinity hazard. (In the



by **Dr. Ir. B. Verhoeven,** *Zuider Zee Polders Development Authority, The Netherlands.*

Netherlands, saline groundwater 3 ft. below the soil surface may be acceptable, but in Pakistan a water-table 10 ft. below the soil surface does not always prevent salinity.) Other factors affecting salinity include distribution of rainfall, soil type, and quality of groundwater. Not all saline soils owe their origin to capillary transport from the water-table. Flooding or spraying with sea water, salt-loaded rains and wind movement of salt crusts are among the phenomena which can also cause salinisation in some locations.

Occurrence of Saline Soils

Saline soils are found in south-east Europe (Russia and the Balkans), in north Africa (from Morocco to Egypt and in the Sudan), in South Africa, throughout southern Asia (Israel, Syria, Iraq, Iran, Afghanistan, Pakistan, India, China), in Australia and in south and north America (Argentine, Chile, Puerto Rico, Mexico, USA).

While saline soils may form extensive salt deserts, semi-deserts, or steppes (such as the 'white puszta' in Hungary), they may also be found as small patches in an area of non-salinised, often highly productive soils. This alternation of good and bad patches is characteristic of many saline soils.

Although in nearly all these areas the saline soils were originally confined to the lower—not always the lowest—places, their occurrence has often been considerably promoted by the introduction of irrigation. Irrigation schemes without adequate drainage systems invariably cause—sometimes rapidly—salinisation of part of the irrigated area as well as of parts of the adjacent land. The effect of local over-irrigation and leakage from unlined canals, to some extent unavoidable, is not necessarily harmful, provided drainage is adequate. Even the cultivation of virgin land, without irrigation, may change water movements so substantially (e.g., by replacing perennial, deeply rooted native grasses by annual crops with more restricted root systems) that at the lower places the water-table rises to a critical level.

Saline or alkali soils are also found on former sea bottoms along sea coasts, where saline soils may be present even in humid areas (Netherlands, Germany), and in places, such as Iraq, where salts have accumulated as a result of faulty irrigation in earlier times.

Characteristics and Classification

In every soil the soil solution contains some salts; in normal soils they amount to 0.025-0.005 per cent. of the total dry soil at the most, and the salts are usually mainly bicarbonates of calcium. In soils contaminated by sea water, on the other hand, the salt content may rise to 0.6-0.8 g. per 100 g. dry soil, and in the top few inches of a salt desert a pure salt crust may be found.

Whether plant growth is possible or not, and which plants, if any, will thrive, which will wilt and which will not develop at all, depend upon the degree of salinity; the kind of salts is also of some importance, in particular at the lower salt concentrations, and often the unfavourable effect of one ion may be reduced by the presence of another. The salt tolerance of both wild and cultivated plants varies widely.

Sodium chloride forms 85 per cent. of the salt content in soils contaminated by sea water; in other soils sulphates (including gypsum, calcium sulphate), sometimes carbonates and exceptionally nitrates are of importance. Magnesium salts are found in considerable quantities in some saline soils.

Soil moisture containing a high concentration of dissolved salts has a high osmotic pressure, and this is generally regarded as being the most important factor in impeding utilisation by the plant.

A more persistent problem arises when a saline soil has a bad structure. The fine soil particles have a negative electrical charge and so absorb cations. In normal soils calcium ions account for at least 80 per cent. of the total adsorbed cations. In saline soils this adsorbed calcium may

be replaced largely by sodium, which results in a change in the physical properties of the soil and the appearance of the notorious sodium soil characteristics: sticky when wet, stone-hard when dry; between wet and dry the soil workable only for a very short period; low permeability; formation of a crust.

Various systems have been proposed for classifying saline soils. The most modern classification is probably that introduced by the US Salinity Laboratory. This is based on the salt concentration of the soil moisture, measured as the electrical conductivity of a saturated soil extract, EC_e, and expressed in millimhos (reciprocal milliohms), and on the proportion of adsorbed sodium ions, expressed as a percentage of the total adsorbed cations, ESP. There are three groups:—

1. *Saline soils.* Conductivity of saturation extract higher than 4 mmhos/cm. and ESP less than 15. The pH is usually below 8.5, which means that the soils are not strongly alkaline.
2. *Saline-alkali soils.* EC_e more than 4 mmhos/cm. and ESP higher than 15. These soils, too, generally show a pH below 8.5.
3. *Nonsaline-alkali soils.* EC_e less than 4 mmhos/cm. and ESP higher than 15. Such soils may be clearly alkaline with pH values between 8.5 and 10.

Table 1 indicates the relation between EC_e, the salt content and the tolerance of the crops. (From *Diagnosis and Improvement of Saline and Alkali Soils*, by the staff of the US Salinity Laboratory—USDA Agriculture Handbook No. 60—and supplemented by Zuur.)

Table 1

Salt content in root zone and plant growth (medium soils)

	EC_e	*Salt content (% on dry soil)*
Salinity effects negligible	0	
Yields of very sensitive crops may be restricted	2	0.05-0.1
Yields of many crops restricted ..	4	0.1-0.2
Only tolerant crops yield satisfactorily	8	0.2-0.4
Only a few very tolerant crops yield satisfactorily	16	0.4-0.8

The EC_e and ESP values give a fair characterisation of saline soils, but often other facts have to be studied. For example, the presence of calcium sulphate in the soils may make reclamation easier; in saline soils boron may be found in concentrations toxic to crops (which as a rule are highly sensitive to boron)—in such soils attention has to be paid to the leaching of the boron.

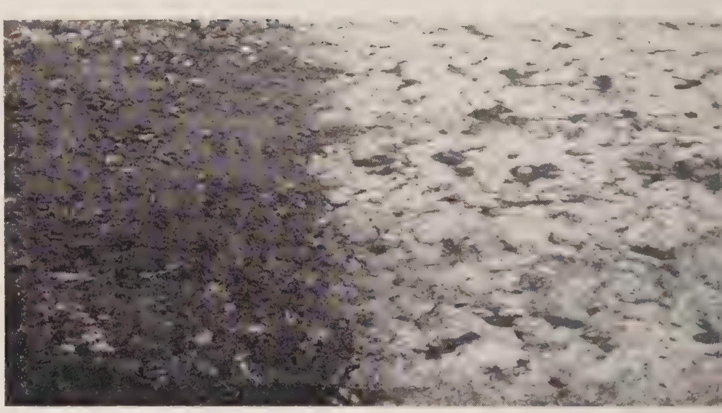
Reclamation

The first step in reclamation generally is to remove the cause of soil salinity—i.e., the high water-table. This means that the first requirement for sound reclamation is to ensure adequate drainage facilities. The next action must be to leach out the excess of salt: sometimes the rainfall is sufficient to do this but it will generally take too long and often may not even bring about a measurable decrease of soil salinity. Usually, therefore, irrigation systems have to be installed to promote the leaching of the salt. In some soils, however, permeability is so low that leaching is virtually impossible; in such cases improvement of structure is a prerequisite for successful leaching.

Saline soil reclamation usually requires a lowering of the water table, which calls for fairly deep drainage (4 ft. 6 in.-6 ft.), the depth depending on various factors such as climate, soil, quality of water and irrigation technique. In some cases, however, good results have been obtained with shallow drainage and strictly controlled irrigation. A large quantity of water is needed for leaching the salt, but the leaching itself is often not particularly difficult, provided the water is available, and the ESP is low. Then soil structure will not be affected, and permeability of the topsoil will generally be reasonably good. A combination of

Examples of normal and abnormal soils. On the left, normal; on the right, a similar type of soil, but in a nonsaline-alkali status, resulting from flooding with sea water and subsequent leaching with rain water. Both samples were dropped from a height of 3 ft.

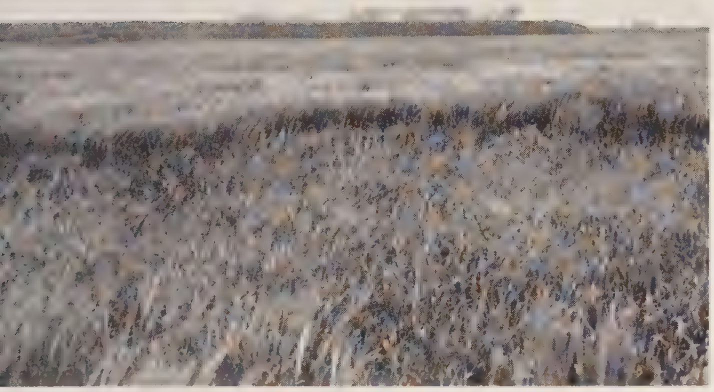
(Photo: Directie van de Wieringermeer, Holland.)



Effect of gypsum on barley growing on c nonsaline-alkali soil. No gypsum was applied to the plot in the foreground the remainder of the field receivec varying amounts

(Photo: Directie van de Wieringermeer, Holland.

Effect of gypsum on the structure of a nonsaline-alkali soil. Right, *untreated;* left, *a plot treated with gypsum at about 12 tons per ha.*
(Photo: Directie van de Wieringermeer, Holland.)



deep drainage and irrigation will normally be sufficient to bring about reclamation.

Saline-alkali soils are more difficult to reclaim. In an unreclaimed state they are often hard to distinguish from simple saline soils. But as soon as leaching has removed the bulk of the salt, the detrimental effect of the high ESP becomes evident through a rapid deterioration of structure. This decline has to be prevented by applying a chemical which replaces the exchangeable sodium by calcium. A chemical often used is gypsum, which may be dissolved in the irrigation water or spread over the land. Apart from this need for gypsum the whole reclamation resembles that of the saline soils.

The nonsaline-alkali soils present more problems. Here drainage is sometimes required not for lowering the water-table, but simply for preventing a rise of groundwater level after the introduction of irrigation. The structure of these soils is often so bad that large amounts of gypsum are needed, and permeability may still remain poor; thus the main problem may be how to get the water into the soil. It may be useful to improve the permeability by deep tillage, but experience with such treatment has only been obtained locally, and attempts have not always been successful.

Economics of Reclamation

Whether or not it pays to reclaim a certain area of saline land depends on many factors. Rural over-population may cry out for new land; the economy of the country may demand an increase in agricultural production. Both reclamation costs and the value of the reclaimed land vary widely. As most saline areas are fairly low-lying, reclamation may comprise protection against floods, the excavation of a main drainage system, building a pumping station, establishing irrigation schemes, and constructing farm drains. In other cases one ditch connecting the saline area with a nearby river will be sufficient.

In countries where crop yields on normal soils are still far below the economic optimum it is often more advantageous to use available funds to increase the production of soils under cultivation than to reclaim salinised land. If, however, agriculture is already highly developed, and though all the good soils are in use, they are insufficient for the farming population, it is useful to consider the reclamation of saline land.

The cost of irrigating saline soils (category 1, above) is usually little more than for normal soils, but drainage may be more expensive because the land is low-lying. Drainage with tiles (manual work) takes 25-30 man-hours per hundred yards and a few hundred yards more per acre is not a great problem.

Compared with simple saline soils, the saline-alkali soils need chemical treatment (e.g., with gypsum or sulphur) as well as irrigation and drainage. Often the price of gypsum is low, when the operation will depend upon transport costs, which may be prohibitive in countries where transport facilities are poor. The quantities of gypsum used amount to 8 tons per acre—sometimes even more.

Finally, the nonsaline-alkali soils can be the most difficult to reclaim. In semi-arid areas application of gypsum combined with the rainfall may bring these soils into reasonable production; but usually they need drainage and irrigation as well, and the latter is impeded by the impermeability of the top soil. Even after reclamation these soils, which often have an unfavourable profile during the period of alkalisation, may not be classified among the best.

The cost of reclamation may vary from little more than £35 to little short of £350 per acre. Where necessary for new land it may be best to study the possibility of starting with a small project, in order to gain experience and to accustom government authorities to the idea of spending money on reclaiming saline land. These initial projects should not, of course, be allowed to hinder later schemes.

At present, saline soil reclamation may sometimes seem, or in fact may be, too expensive. The rapidly growing world population, however, will sooner or later compel man to reclaim all the land that can be made fit for crop production. Saline and alkali soils can usually bear crops, provided water is available and the right method of reclamation is applied.

International seed training course in U.K.

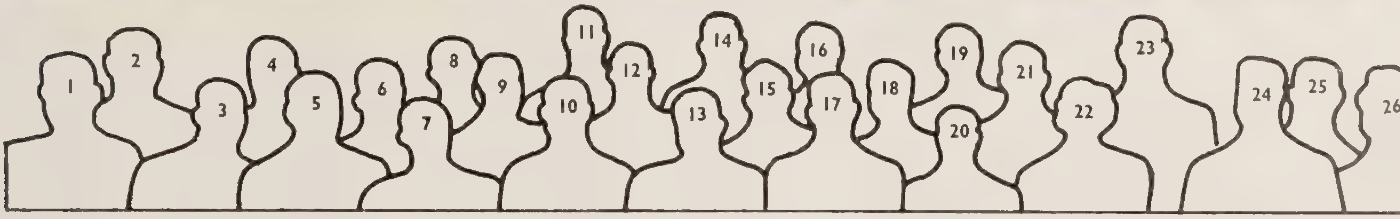
As a contribution to the FAO International Seed Year, the United Kingdom recently provided a six weeks' seed training course for 27 representatives from countries in Europe, Asia, the Middle East, Africa and Latin America. The course was held at the National Institute of Agricultural Botany, Cambridge, during June and July.

The United Kingdom has reached an advanced stage of development in seed techniques, and the use of seed of improved plant varieties bred to suit British conditions has made a major contribution to the marked increases of both cereal yields and grassland production during the last few decades. Because much of the plant breeder's work would be wasted unless farmers were certain that the seed they bought was true to its description, the UK had established seed certification schemes, and testing services to complement them.

A knowledge of the various practices involved in seed production, certification and testing can be of immense help to the developing countries in promoting the production and use of improved seed—an essential factor in raising food production and living standards—and it was this knowledge that the course at Cambridge was designed to provide.

The course was divided into two parts: four weeks of seed analysis (purity, germination, seed health, legislative control and advisory work); and two weeks on production (improvement and assessment of varieties, seed multiplication, certification and supply and distribution). As the course was attended in the main by senior technical staff, emphasis was laid on the organisation and administration of technical services which form the basis of seed control, including the design of laboratories and equipment and the training of staff. A number of visits were made to seed growers and merchants and to research stations interested in different aspects of seed work, including Shell's Woodstock Agricultural Research Centre.

D. B. Mackay, staff, NIAB; Tang Teng Lai, Malaya; Tae Dong Lee, Korea; U. Aye Myint, Burma; S. Vaidhyakarn, Thailand; L. F. Pilsworth, staff, NIAB; S. Moutia, Mauritius; G. Khandaker, Pakistan.



Members of the international seed training course held in Britain:

1 A. Kacala, *vice-director, Plant Production Department, Poland.*

2 B. Sigurbjornsson, *plant-breeder, University Research Institute, Iceland.*

3 V. C. R. Henry, *agronomist, Trinidad.*

4 V. Cardozo, *lecturer, University of Asuncion, Paraguay.*

5 J. M. Pire, *agricultural inspector, Spain.*

6 G. Morales, *professor of agriculture, Costa Rica.*

7 S. Vaidhyakarn, *rice seed technician, Thailand.*

8 M. S. Soudi, *agricultural lecturer, Jordan.*

9 N. Aristotelous, *agricultural superintendent, Cyprus.*

10 G. Khandaker, *assistant director of agriculture, Pakistan.*

11 A. C. Macintosh, *agricultural research officer, Basutoland.*

12 M. I. Samater, *agricultural advisory officer, Somalia.*

13 B. Gunay, *director of Seed Testing and Certification Institute, Ankara, Turkey.*

14 S. Moutia, *horticultural officer, Mauritius.*

15 H. Campos, *director of Agronomy Institute, Maracay, Venezuela.*

16 H. A. Sheybani, *director of agronomy research, Iran.*

17 Tae Dong Lee, *secretary, FAO Association, Korea.*

18 M. I. Jehani, *assistant agronomist, Libya.*

19 Tang Teng Lai, *botanist, Department of Agriculture, Malaya.*

20 U. Aye Myint, *district agricultural advisory officer, Burma.*

21 J. E. Holguin, *head of national campaign for seed production, Colombia.*

22 Mrs. M. L. Hinojosa de Fernandez, *head, Department of Plant Hygiene, Bolivia.*

23 M. I. Hakki, *agricultural assistant, Cyprus.*

24 J. R. Raimundo, *department head, Seed Testing Station, Portugal.*

25 V. Jasnic, *assistant professor, University of Belgrade, Yugoslavia.*

26 Miss A. Gordin, *research worker, Beit Dagan, Israel.*

More pictures on next page

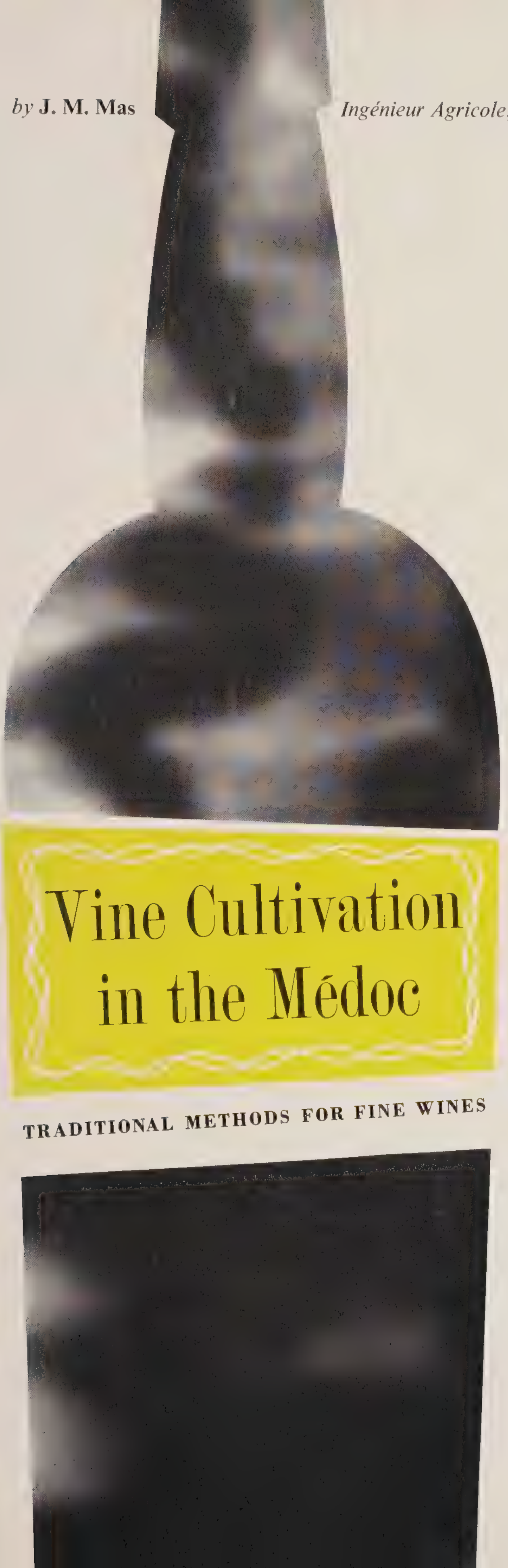
G. Morales, Costa Rica; J. E. Holguin, Colombia; V. C. R. Henry, Trinidad; H. Campos, Venezuela.

Miss A. Gordin, Israel; M. S. Soudi, Jordan; B. Sigurbjornsson, Iceland; B. Gunay, Turkey; A. Kacala, Poland (behind); *M. I. Samater, Somalia; Dr. P. S. Wellington, chief officer, Official Seed Testing Station, NIAB.*

A. C. Macintosh, Basutoland; J. R. Raimundo, Portugal; Miss Baynard, staff, NIAB; N. Aristotelous, Cyprus; P. Hayes, Northern Ireland. Seated, *Miss Hopkins, Miss Ford and Dr. Wellington* (back to camera) *—all staff, NIAB.*

A. C. Macintosh, Basutoland; H. A. Sheybani, Iran; M. I. Jehani, Libya; Miss Ford, staff, NIAB.

by **J. M. Mas** *Ingénieur Agricole, Regional Inspector, Institut National des Appellations d'Origine*[1].



Vine Cultivation in the Médoc

TRADITIONAL METHODS FOR FINE WINES

North of the city of Bordeaux, in south-east France, and on the left bank of the Gironde, lies the district of the Médoc, an area some 50 miles long in which vineyards occupy a strip six or seven miles wide, bordering the estuary. From this district come some of the finest and most famous wines produced not only in France, but in the world. In the following article the author sets out to show how far cultivation methods are a factor in producing wines of high quality.

Although over the years methods of cultivating vines and producing wine have changed considerably to keep pace with economic conditions, the principles applied in the Médoc in the past have remained unaltered, and it is rare in France to find vineyards which are so faithful to tradition as those of the Médoc. Today, the appearance of these vineyards, with their densely planted, extremely low vines, is very characteristic.

In theory, the distance between the plants is 3 ft. 3 in., giving a density of 4,000 vines per acre, but in practice the inter-row space is often just under 3 ft. and the plants are spaced 3 ft. 4 in. or 3 ft. 8 in. apart in the rows. In new vineyards, however, the system is more flexible, and the tendency is towards a greater distance between the *règes* (rows of vines) to give access to mechanised equipment; rows may now be 4 ft. 11 in., 5 ft. 3 in. or even 5 ft. 10 in. apart, which reduces the density to between 2,400 and 2,600 vines per acre.

The vines, which are trained very low, are most distinctive. The first sight of the Médoc vineyards is very striking, with the vines trained down almost to ground level, and the leaves thinned out to the minimum. Beside each vine, the stem of which is scarcely more than 6-8 in. high, is a *carasson*, or small stake, 1 ft. 2 in. to 1 ft. 4 in. high; these stakes are linked by a wire to which the *astes* (long branches) are attached, slightly curved over. (The wire is a recent innovation; in the past long deal laths were nailed to the tops of the stakes.) The current trend is to fix a second wire about 1 ft. 8 in. to 1 ft. 11 in. from the ground, and sometimes even a third wire, so that the plant may develop in a more natural manner.

The method of pruning the vines has remained traditional; its origin goes back a very long way, and the principle of pruning is described by the Roman agronomist, Columella, as: 'dividing a layer into two branches, in order that, for economy, it may cover two supports instead of one'.

The type of pruning now employed is known as 'Guyot double' and differs very little from the type of pruning

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[1]An *Appellation d'Origine* is a specification for the production of a particular wine which is to be sold with its name and place of origin on the bottle. It can include such details as the variety of grapes to be used, the area in which they must be grown, the maximum yield of wine (gallons per acre), and the sugar and alcoholic contents of the wine.—Ed.

carried out in the old days in the Médoc: the first, preliminary pruning, known as *anquage*, leaves two branches on the trunk; each branch bears one shoot with an average of four to six lateral buds, and one renewal spur pruned down to two buds; it is this spur which will be pruned the following year when the fruiting branch is cut away. In the old days there was no renewal spur, and as a result the branches increased considerably in length, so that sometimes branches which had developed to excess had to be replaced.

Authors writing in the last century (2) tell us that rather more than one hundred years ago the vines of the Médoc were ploughed no fewer than four times: the first ploughing took place in mid-February, and was intended to uncover the foot of the vine; labourers took the soil from between the vines and moved it into the furrows. This operation was carried out with a plough known as a *cabat*. In April a second ploughing, this time with a *courbe* plough, moved the soil back from between the rows to the bases of the vines (ridging). In May, the soil was shifted away again, and in July-August finally replaced. The vine therefore remained uncultivated for six months or more. In general, there has been very little change in this method, but the introduction of surface cultivation during the summer has to a certain extent altered the cycle of ploughing operations, and has sometimes resulted in the elimination of the intermediate operations, and the postponement of the final ploughing until after the wine harvest.

Manuring

The manuring of vines has been a controversial topic since time immemorial. It has been argued that the increased production of wine resulting from heavy manuring might impair its quality, as it was—and still is—very widely held that quality and quantity are incompatible. Nevertheless, it used to be the custom to manure when planting out the vines, and manuring was in fact often fairly heavy—'60 cartloads, or 60,000 kg. per *journal* [an old surface measurement, corresponding to the area which could be ploughed by one man in one day], i.e., 72 cartloads to the acre' when vines were planted in ordinary soil or in a lande[1]. In vineyards which were being renewed or replanted, twice as much manure was used, in addition to 360-480 cartloads of good soil per acre. In addition, it was not unknown for vines to be manured during their lifetime, either with farmyard manure or with compost. This would be done every three or four years, the manure being applied to alternate rows (*chambert* method[2]).

Today, while it is realised that to some extent quantity does not exclude quality, vines are not heavily manured. Few vineyard owners plough in heavy applications of manure when trenching; more manure their vineyards periodically, although they are still in the minority. There are two reasons for this: first, the high cost, particularly with labour scarce and expensive, so that manuring is virtually impossible; and secondly, the lack of farmyard manure itself. In the absence of farmyard manure, inorganic fertilisers are now used; they are better than nothing, but one vital factor is missing—organic matter, which is becoming increasingly scarce. But this is another problem.

Such are the methods of cultivation formerly used in the Médoc, and still in use today, more or less unchanged. Now that modern methods are fashionable, mechanisation is intensive, and tall vines are the order of the day, the slowness of progress (or, according to some people, the lack of it) may seem surprising. But one vital point must never be forgotten: the main concern of the vineyards of the Médoc is quality above all else. Desirable though progress may be, there are still certain tasks which cannot be dispensed with if quality is to remain unimpaired.

Growing for Quality

In vineyards where quality is the main concern, the type of both soil and vine determine the row spacing selected. The poorer the soil, the closer should the vines be planted; the lower yielding the variety, the more vines must be grown to make the best possible use of the area under cultition. In the Médoc, the soil is mostly gravelly and poor, and the *alios* (a sub-soil containing hardened ferruginous sand) is frequently only a few inches from the surface. The varieties of grapes grown are 65-70 per cent. Cabernet-Sauvignon and Cabernet-franc (low or moderate yielding) and 25-30 per cent. Merlot; in certain districts a small area of Petit Verdot is also grown.

The training, pruning and thinning of the vines are all arduous tasks. Writing a century ago, D'ARMAILHACQ (1) states: 'In the Médoc, where the climate is slightly cooler than in the South of France, though almost as dry during summer and wetter during autumn, we try to keep the grapes in the shade, as in the Midi, and, so that they can make maximum use of the heat, close to the ground—but not touching it as the moisture would rapidly rot them'. 'It is unfortunate,' he concludes, 'that all this should entail such great expense, but the result is a degree of perfection which otherwise would never be attained.'

This perfection is the constant aim of the vine-growers of the Médoc. One needs to live close to the vineyard-owners and to the *maîtres de chais* to realise how devotedly they cultivate their vineyards throughout the year, and with what affection they tend their wine from the moment it flows from the vat to the time it is bottled, and to understand that in the Médoc 'quality' is not an empty word.

In the Médoc there has been handed down over the centuries a tradition whose roots go deep and which may be looked upon by some as ingrained, for it is firmly opposed to everything which is too modern. It is nevertheless a valid tradition, and not without reason, for it has resulted in the prestige of the wines of the Médoc standing high throughout the world.

[1]A sandy soil, often resulting from deforestation, typical of the Bordeaux region.

[2]A method of manuring, whereby a trench 20-24 in. deep was dug between alternate rows, into which the manure was emptied from barrows.

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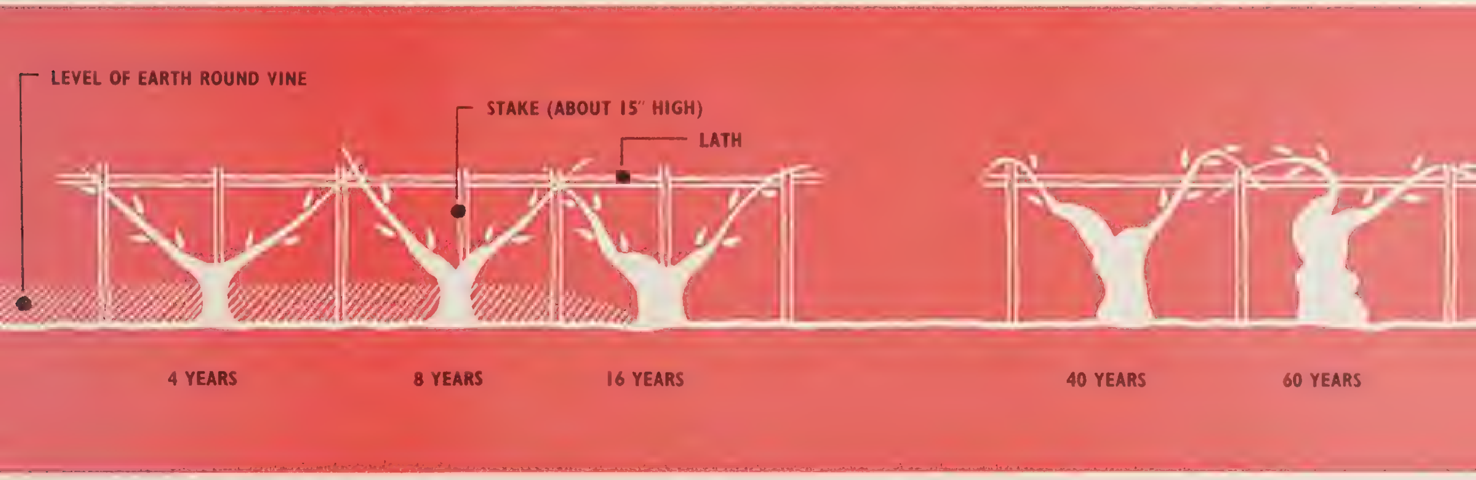
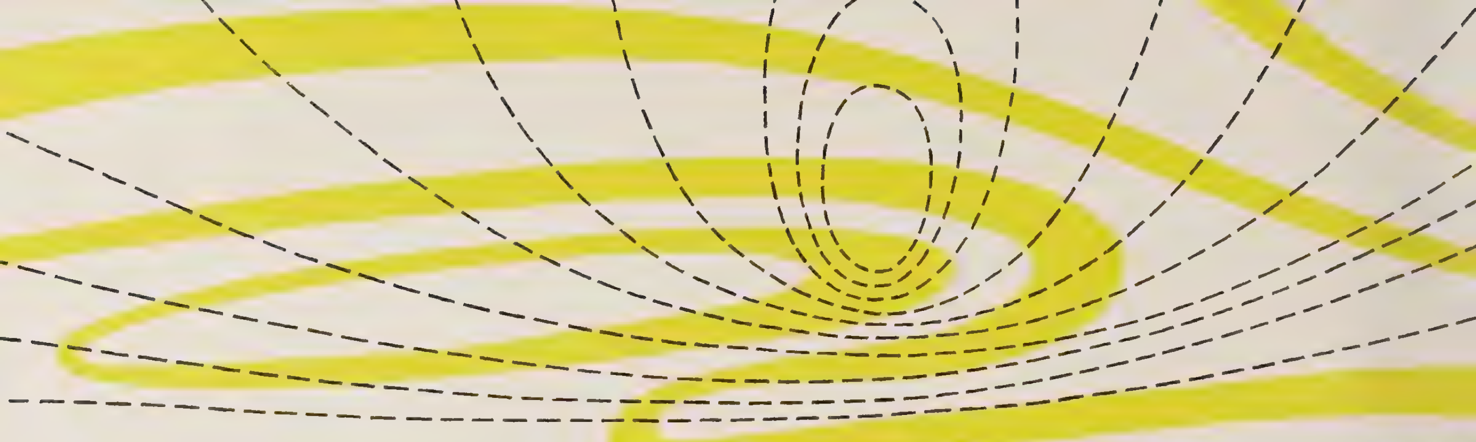
(2) FRANCK, WILLIAM: *Traité sur les vins du Médoc*. P. Chanos, Bordeaux, 1st edition 1845; 2nd edition 1853.

A Médoc vineyard showing the type of training and pruning employed.

The appearance of vines at different ages in a standard row in the Haut-Médoc (after Guyot, Etude des Vignobles de France; *Masson et cie., Paris, 1868).*



Vines in full leaf in the Médoc.



HOW FAR AHEAD

by **R. C. Sutcliffe,** C.B., O.B.E., Ph.D., F.R.S.,
Director of Research,
Meteorological Office of Great Britain.

In every advanced country in the world the general public are familiar, through press, radio and television, with weather forecasts for a day or so ahead. These are not always correct (some critics would call this an understatement) but in fact they maintain a useful standard of accuracy and are much valued for those activities which are greatly dependent upon the weather.

Agriculture provides many interested customers, and there is reason to believe that the regular and wise use of forecasts brings much profit in the planning of the day's work. But how much more valuable would it be if we could see a month or a season ahead, so allowing operations to be planned with less of the element of gambling. Should ploughing or sowing or spraying be early or late? Should one irrigate or trust in future rain? Should the harvest be hastened or taken safely at more convenience? Should stock be built up or reduced?

There are endless questions from which a knowledge of future weather would take away much of the headache, but unfortunately the required forecasts are not provided. Sometimes critics imply either that the forecaster is deliberately keeping useful information to himself because he does not like to risk his reputation or, alternatively, that he is an incompetent scientist who in these days of scientific research ought to have solved the problem long ago. I want therefore in this article to explain the nature of the scientific problem, to show why it is so difficult to solve, to indicate the lines on which research is going and to hazard a guess on what is likely to be accomplished in a reasonable time.

The essential basis of short-range forecasting is well known to everyone with a modest interest in the subject, and especially so to those who through television have become accustomed to the forecaster's weather maps (or synoptic charts) and familiar with his technical vocabulary, his depressions and anticyclones, fronts and the like. We may then quickly remind ourselves that the weather over the world at any time has a pattern or structure which is readily revealed when weather maps are drawn and analysed, as they are several times every day at a main forecasting centre. Hundreds of weather reports from near and far are collected by land-line or radio and quickly assembled to present a comprehensive picture.

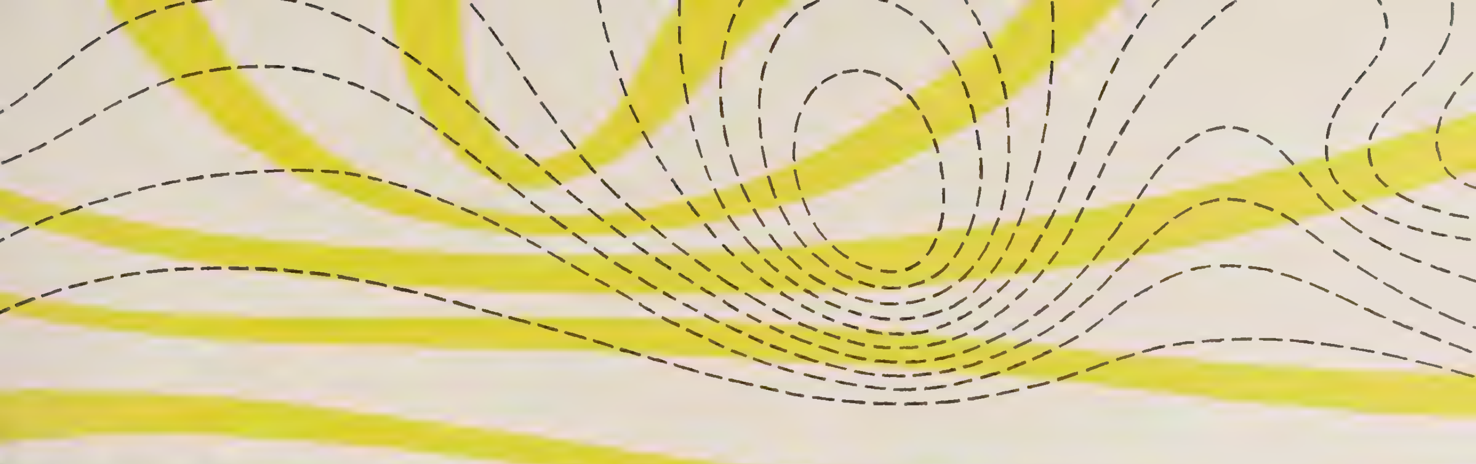
We cannot summarise in a few words the subject matter of standard text-books, but in the broadest outline the lesson quickly learnt from the maps is that weather over the world is organised on a large scale with some areas, perhaps 1,000 miles across, experiencing dry weather, mostly with little cloud (in anticyclones), and other adjacent areas (depressions) mostly cloudy and including belts of rain or showery regions.

These large systems move from place to place at varying speeds averaging about 20 mph (500 miles per day) and bring the corresponding changes of weather. At the same time the winds vary in direction and speed and the air temperatures rise or fall as the current of air comes from a warmer or a colder part of the world. By calculating the speeds of movement and allowing for other changes, rather precise statements can be made with good accuracy for about a day ahead (e.g., rain in the afternoon, followed by a fine night), and less precise but still useful statements may be made for three or four days (e.g., further rain on Tuesday but probably followed by dry weather for a day or two). The detailed forecasts for about one day ahead we call 'short-range', the less detailed covering a few days are 'further outlooks' or 'medium-range forecasts'.

Naturally, the problems are not identical in all parts of the world and forecasting for the polar regions, for the tropical deserts, for monsoon climates, or for the equatorial rain-belts has, in each case, its characteristic features. Indeed, the broad division of weather into large anticyclonic and cyclonic areas does not apply satisfactorily in equatorial areas. But in spite of these differences the conclusions drawn above are broadly true for the whole world.

Detailed Forecasting Impossible

It may be said, with as much confidence and unanimity of opinion as science generally permits, that at the present time there is absolutely no method of estimating the changes of weather from day to day for more than, say, four or five days ahead. No scientist of standing would



CAN WE FORECAST THE WEATHER?

either attempt to say what the weather would be on a certain day a month ahead in a country with changeable climate, or, and this is much more remarkable, would hold out any promise of such a prediction becoming possible as a result of scientific research unless some radical discovery should emerge.

The turbulent patterns of weather systems, depressions and anticyclones move and change so rapidly that after a few days all detail is lost. Although we know there will be depressions and anticyclones somewhere, and past records have taught us what to expect for the place and the season of the year (i.e., we may know the *climate* very well), it seems foolish to ask where each weather system will be on any one day and so to foretell what weather will occur within the wide range of climatic possibilities. Indeed anyone who claims, in the present state of scientific knowledge, to foretell the variations of weather from day to day more than a week or so ahead is either unconsciously deceiving himself or attempting to deceive others: he is in the crudest terms either a fool or a fraud.

However, I do believe there is a fair chance of our being able to predict the general character of a month or a season ahead with quite useful accuracy. If we could do this with reliability and only say in what parts of the world next winter would be unusually mild or severe or next summer unusually dry or about average, we should have information which, properly used, would be worth untold millions in terms of agricultural efficiency, fuel economics and international trade: unexpected floods in China or droughts in Africa may be events to shake the world.

The prize to be won by success in long-range forecasting, even in broad terms, is so tremendous that research is justifiable if it offers any chance at all and the present time may be favourable for stepping up the effort. It is undoubtedly true that, whether we can forecast these things or not, there are remarkably large variations, as for example between the English summers of 1959 and 1960, amongst the finest and the wettest in our records. Why was this so? Quite frankly, we do not know. Certainly in 1959 the rain-bearing depressions failed to pass over England and moved preferably to the south or far north, while in 1960 there was one disturbance after another. But this only puts the question back a stage and sets the more technical but no less difficult question: why did the weather systems move so differently across the face of the earth in those two summers? In other words, why was the general circulation of the atmosphere so different in the two years? Within narrow limits there was no obvious physical difference between the two years other than in the weather itself: could this difference arise with no specific cause?

World Climate

To give an intelligent answer to this question we must first study the problem of the general circulation of the earth's atmosphere or, what is much the same thing, the structure and theory of world climate. Most people are familiar with the main climatic zones—the icy polar regions, the very variable unsettled weather of our middle latitudes, the Mediterranean type of climate with its fine summers and rainy winters, the sub-tropical deserts, the tropical rains, and the monsoon climates, such as are experienced in India or West Africa, with alternating dry and rainy seasons.

As we go through each year the seasons change in all parts of the world. The polar regions of summer are continuously sunlit and the climate often quite pleasant; the weather of middle latitudes is warmer and less stormy than in winter; the interiors of the large continents become very hot after the extreme cold of winter. There is in fact a complicated annual rhythm which goes on year after year and indeed defines what we call climate; and when we remember that the weather is made up of a mixture of quiet periods and storms of various kinds we can hardly expect all the years to be exactly alike.

The crucial question is this: could it be that, as the annual rhythm goes on its sluggish way taking weeks and months to change from one regime to another, the great wind currents vary as uncertainly as a river in a silted estuary, slipping each year into rather different channels, due to a cause so complex and unpredictable that the annual choice could just as well be pure chance? What channel will be followed by the raindrop trickling down the window? What place will be chosen for the next flash of lightning to strike? The material world abounds in physical problems so complicated that there seems no practicable way of setting about their solution. Is it possible that long-range forecasting is one of these?

This may well be so. It may be that the variations in weather from year to year are merely different channels

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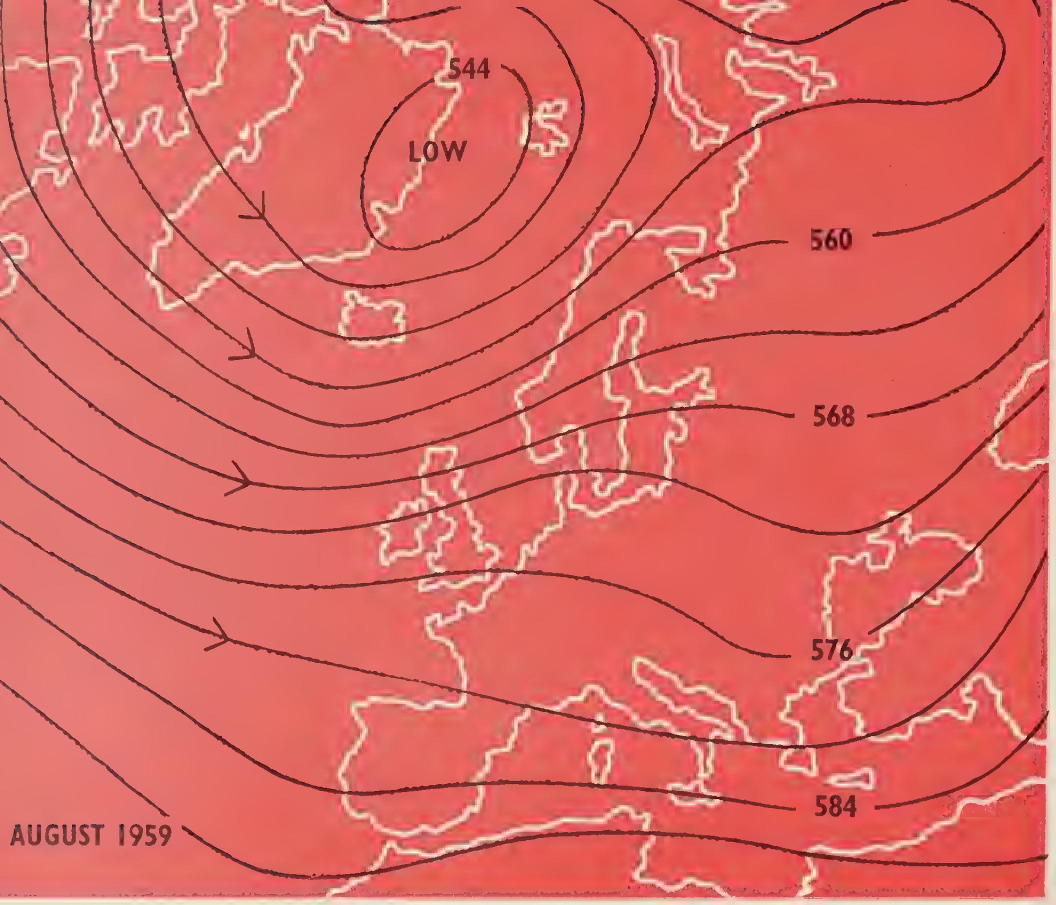
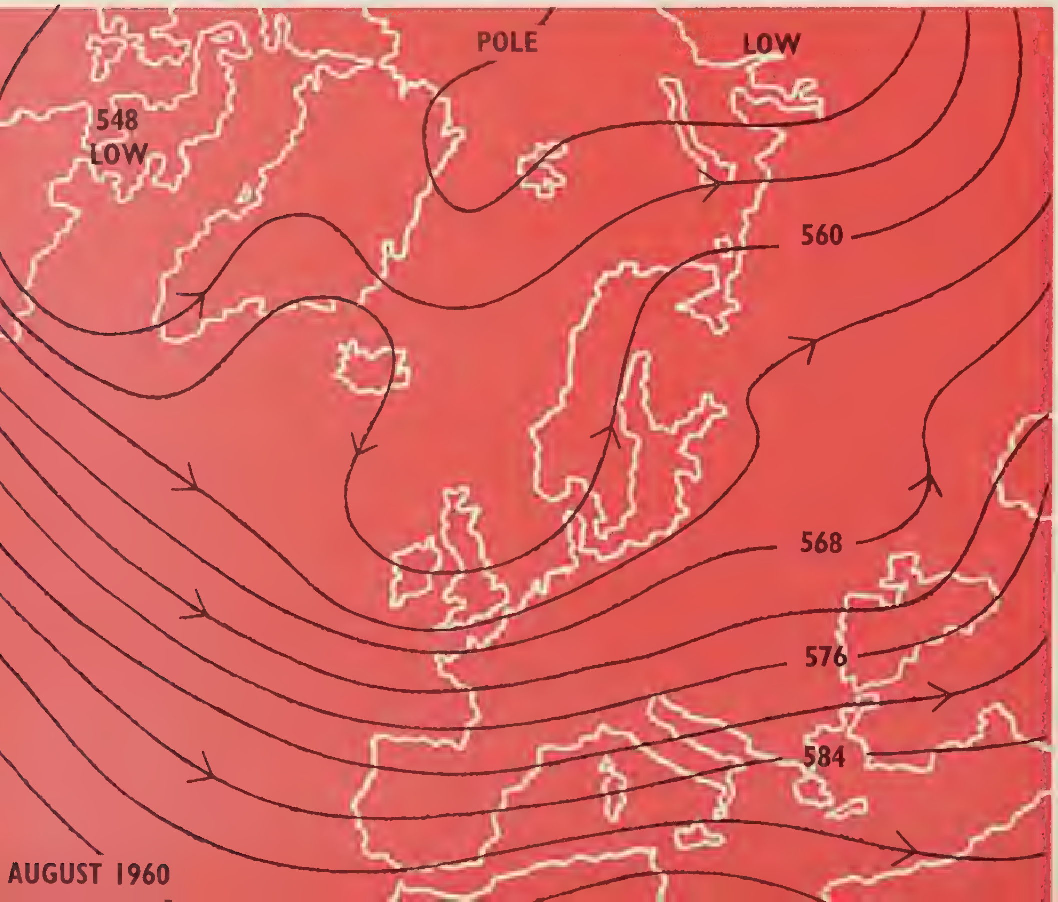


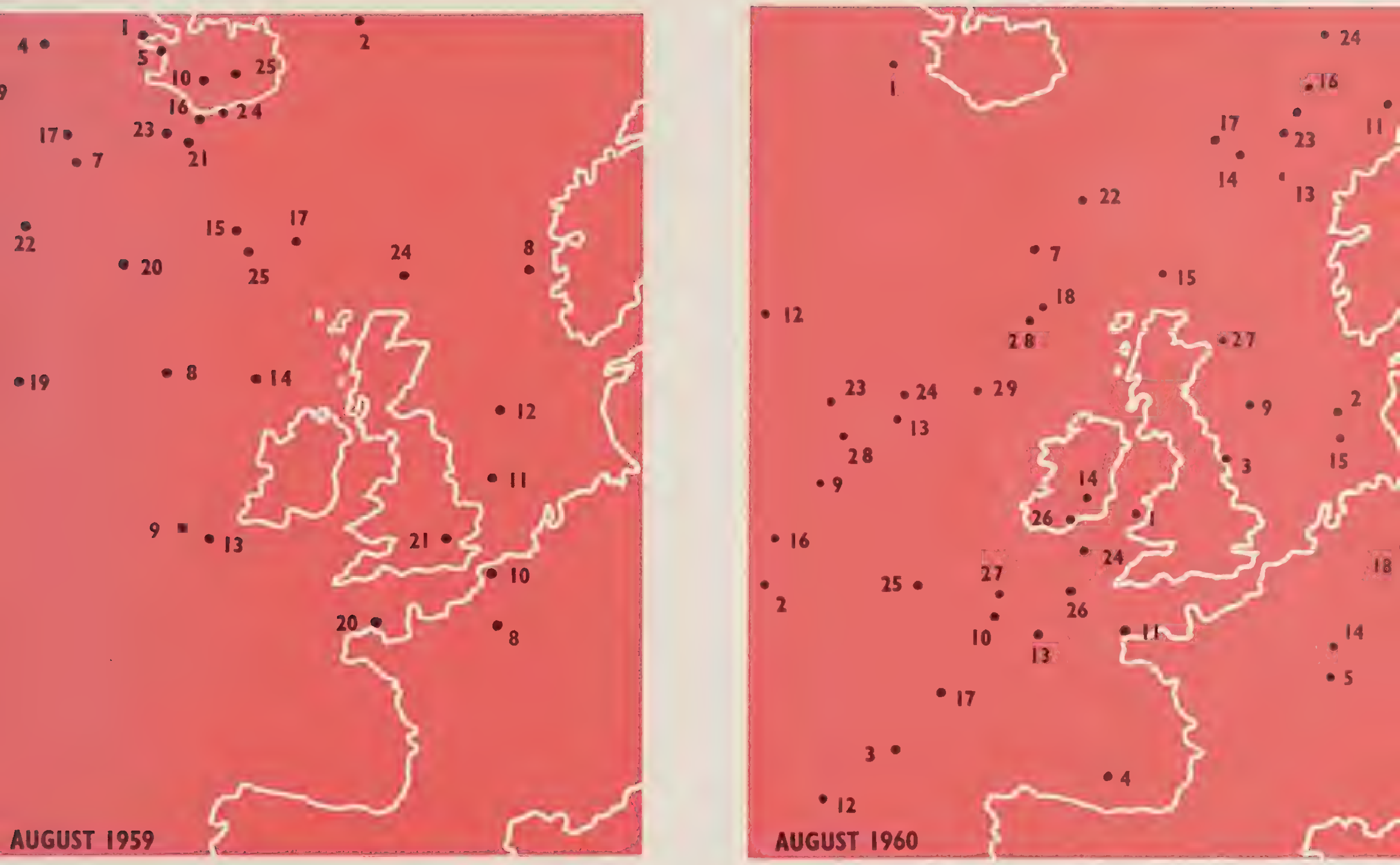
AVERAGE CONTOURS OR APPROXIMATE STREAMLINES
AT 500 mb. HEIGHTS IN DECAMETRES.



The diagrams on these pages illustrate the large differences between two summer months in England: August, 1959, which was warm and sunny, and August, 1960, which was cool and wet.

The contour charts (left) for 500mb (about 18,000ft.) show how in 1959 the main flow was north of the British Isles, while in 1960 it was to the south across France.

Right: these diagrams show the centres of depressions on each day of the month. In 1959 they passed mainly to the north, while in 1960 they passed near the British Isles with practically none over Iceland. The scientific reason for these big differences in consecutive years is not known.



POSITIONS OF THE CENTRES OF DEPRESSIONS
AT MIDDAY ON EACH DAY OF THE MONTH.

chosen by the wind currents as they find their way afresh each year over the oceans and lands around the great mountain obstacles and across the open plains. Some slight difference at a critical time and place may start the annual rhythm on a different road from one year to the next, and although the cause is there it may for all practical purposes be an unpredictable accident. However, it is almost certainly not beyond us to discover the true explanation, and if research can do this it is only a question of time and effort.

Research Requirements

First, we badly need a quantitative theory of climate, of the circulation of the winds over the planet Earth. For this the major need at present is probably brain-power, the basic theoretical skill to tackle a very difficult and complicated problem, and some progress is being made, so far notably in the United States.

One obstacle has been the lack of large-capacity electronic computers to carry out the heavy calculations, but these are quickly becoming available to meteorologists in many countries. The Meteorological Office of Great Britain has possessed for two or three years an advanced computer costing about £100,000, and even this may not be adequate for all purposes.

Another obstacle, which will become more and more serious as theory advances, is the lack of weather data. In spite of the thousands of reports being made every day we still have very little idea of the patterns of winds and weather in the upper atmosphere over large tracts of tropical country and larger stretches of the oceans of the world. The means are available: balloons to rise through 99 per cent. of the mass of the atmosphere, and radio instruments to read the weather elements and transmit the data to us. To use these every day through the year at a sufficient number of places all over the world might cost the world £100 million annually, but it could be a thoroughly sound economic investment.

Then, since all the energy which drives the winds and evaporates the ocean waters to supply the rain comes from the sun, either directly or indirectly after first reaching the ground or ocean, we shall need to monitor this energy. For this we also have the technical knowledge now that artificial earth satellites can be put into orbit to measure both the incoming and the outgoing energy. At the present time it is probably theory that is lagging most, and the need for more expensive data is not so pressing. But no scientist is much attracted to theoretical work if the data to test his results will not be to hand when he needs them. There is no time to lose if progress is not to be held up by lack of essential information.

Established Lines of Investigation

I have said little about the older lines of investigation which have sought to discover means of long-range forecasting by statistical analyses, by hitting upon periodicities or by discovering correlations of the weather with earlier events elsewhere or with solar factors—particularly sunspots. This kind of work has been pursued for too many years with little in the way of convincing results, and I see little prospect of a successful outcome to such studies in the future.

This does not mean that there is no scope for research using modern statistical techniques. The weather is so very variable and complicated that we need good statistical methods just to discover what is happening. By combining sound statistics with weather maps the anatomy of weather is more clearly revealed and a small measure of success, better than chance, in forecasting for a month or even a season ahead seems to be attainable simply by extrapolating wisely.

There is also the so-called method of analogues, whereby one selects from past records the years which behaved in a way most similar, or analogous, to the current year; and then, applying the principle that like follows like, one may make a prediction. This method is not without scientific interest for much is learnt from the comparisons—if only that Nature seems never to repeat herself—and trial forecasts made by the method have been on average rather better than guesswork, although they have also included some very bad mistakes.

If in any country it were decided to issue long-range forecasts for a month or a season ahead, and to accept the fact that they would sometimes be highly misleading, some degree of success would probably be attainable, judged on average results, by a combination of climatology with extrapolation and analogues: and perhaps the success would be improved by skill born of experience. It is by some such more or less judicious mixture that long-range forecasts have been made for many years in some countries, notably in Germany, Russia and the USA, and on rather different lines in India for the following monsoon season. The standard of success is uncertain and I am not sure that satisfactory tests have been made and published, but at least borderline success can be claimed for experiments with which I have been connected. One may be confident that whatever is the success of present-day forecasts all short cuts are likely to reach a dead-end quickly, and that a full and satisfying understanding will ultimately come only from the rigorous disciplines of mathematics and physics.

My own opinion, although it is little more than a guess, is that forecasts of the general character of the weather for about one month ahead will become possible, in that long dry spells, heat waves, persistent frosts and rainy periods may be picked out in advance with more successes than failures. I also expect that near or during the changes of the seasons it will become possible to recognise the way in which the next season is likely to go, at least on some occasions. I cannot, however, see any prospect of successful predictions for a year ahead because I believe too much happens all over the world in that length of time to permit us to see anything through the confusion. Rather than trying to look to the weather beyond a few months ahead I would be disposed to jump forward to periods of tens of years and try to discover long-term trends to a warmer or colder, drier or wetter climate. But this is another problem for another day.

Systemic action of chemicals in plants

by **R. L. Wain,** D.Sc., F.R.S., *Professor of Agricultural Chemistry, Wye College, University of London.*

Many fundamental studies have been made on the mechanism by which certain ions can enter plant roots from the soil solution and thereby play their part in the nutrition of the plant. These ions, however, and certain organic molecules, too, can be absorbed not only by the roots but by the stems and leaves of plants and then move within their tissues. Such effects are of first-rate agricultural importance, for not only does this capacity of the plant for absorption and translocation make it possible to control mineral deficiency conditions, but, as is now well known, certain plant insect pests may be eradicated by means of systemic chemicals which, following application, become distributed within the plant.

Furthermore, the so-called plant growth substances—derivatives of benzoic, phenylacetic and phenoxyacetic acids, for example—are truly systemic since they have to be absorbed and translocated by the plant before they can exert their physiological effects. Some of these compounds are capable of modifying the growth of plants at very low concentrations indeed; in practice they will produce such drastic effects as to eradicate many plant species when applied at 1 lb. per acre or less. This can be achieved without serious effect on cereals or grasses, hence the use of these chemical plant growth regulators in selective weed control.

Considerable research has been carried out in recent years on the possible control of fungal diseases by means of chemicals which might operate within the plant, but although encouraging progress has been made in these directions (see Figure 1), no systemic fungicide has yet reached the stage of commercial use. The problems involved in controlling a fungal pathogen by such means, without causing damage to the host plant, are considerable and much greater than in controlling insect pests with systemic chemicals. For these reasons spectacular progress must not be expected.

Because of the agricultural importance of systemic action generally, it is necessary to have an understanding of the mechanisms underlying intake and transport of ions and molecules; it is not surprising therefore that much attention has been given to the basic factors which influence these phenomena. Important among these are the anatomy of leaves, stems and roots and the structural and chemical characteristics of cuticle, epidermis and phloem and other parts of the plant which influence intake and transport (5).

The form in which the substance is presented to the leaves is also important. For efficient uptake, an even film of the material making excellent contact with the leaf surface is clearly to be preferred to large aggregates of crystals which incompletely cover the leaf. In agreement with this it is found that such properties as the particle size of the material applied, and whether surfactant materials or oils are used to aid dispersion and spreading, are all concerned in determining how much of the chemical will be taken up by the plant.

Lipophilic Properties

Of particular importance, too, is the nature of the plant surface; the cuticle of the leaf, stem and fruits, for example, varies considerably from plant to plant. In most cases

Fig. 1. Effect of a systemic fungicide in reducing the degree of infection of broad bean seedlings with chocolate spot disease. The untreated plant on the left shows more lesions on the leaves than the plant on the right, which has been supplied with a systemic fungicide through its roots.

Fig. 2. Importance of leaf sugar in relation to the movement of 2,4-D in broad bean plants. Except for the controls, one leaf of each plant has been treated. Note severe growth responses on the normal green plants treated with 2,4-D (pot 2) and the absence of response on treated plants grown in the dark (pot 4). However, marked growth effects result when treated plants grown in the dark are supplied with glucose solution through the cut tip of the treated leaf (pot 5).

there are layers of cutin impregnated with wax. The chemical nature of the cutin layer as a whole is extremely complex, but its properties are important since it presents a barrier through which the applied ions or molecules must pass. With an organic substance such penetration is related to its lipophilic properties—such as its solubility in cuticular wax. If the organic molecule is too polar with a high affinity for water and polar substances, it will not, in general, penetrate readily through the cuticle; on the other hand a completely non-polar compound may accumulate in the wax and not pass through. Once within the plant, other barriers exist, such as the protoplasmic membranes of cells through which both ions and molecules must penetrate to reach their site of biological action.

In the case of a physiologically active organic acid, which can be applied either as the weakly dissociated acid or its highly ionised salt, it is usually found that the former is more active than the anion. Thus, dinitro-ortho-cresol (DNC) is more herbicidal than its sodium derivative when applied at equivalent concentrations and 2,4-dichlorophenoxyacetic acid (2,4-D) is more active as a growth substance than its sodium salt. The key to this different biological effect of molecule and ion is the protoplasmic membrane. These membranes are complicated in structure. It has been suggested that they contain a double film of orientated phosphatide ions as well as other materials which are lipophilic (1). Alternatively, the membrane is envisaged as a lipoid barrier made up of steroids, glycerides, free fatty acids and phosphatides bounded on each side by a thin film of protein. The arrangement of these constituents is such that free positive and negative charges arise where certain of the lipoid materials interact with the free NH_2 and COOH groups present in the protein molecules (2).

Both of these concepts, it will be noted, provide for ionic groupings within the membrane and it is probably the positive charges which impede the penetration of a charged

organic anion. An undissociated acid, on the other hand, does not suffer this hindrance and might, therefore, be expected to penetrate such a membrane more readily and thereby produce a greater biological effect. Since there is evidence that the protoplasmic membrane contains hydrophilic as well as strongly lipophilic groupings, the balance between lipophilic and hydrophilic character of a biologically active molecule is also a factor in regard to its ease of penetration.

But whilst lipophilic properties are of importance in this connection, within the plant a systemic molecule must also be translocated. For this to occur the molecule must be 'polar'; it must either itself have sufficient water solubility to move within the transpiration stream, or be capable of combining with some soluble plant constituent which will carry it in solution within the plant. Water solubility is, in fact, often a limiting factor in systemic activity. This is the case, for example, with chlorinated organic insecticides such as DDT, aldrin and dieldrin, all of which have extremely low water solubility and are not systemic. On the other hand, systemic compounds such as the organo-phosphorus insecticides and the hormone herbicides, whilst possessing some lipophilic character, are nevertheless sufficiently polar to be translocated *per se* or combined with other substances within the plant.

Association with Sugars

There is now much evidence that movement of certain systemic chemicals from leaves is associated with the flow of sugars produced in photosynthesis, usually towards sites of high metabolic activity (4, 5). Thus it is found, for example, that whilst a growth substance such as 2,4-D rapidly migrates from a green healthy leaf, only little movement occurs after its application to a young rapidly growing leaf from which sugars are not being exported. Again, 2,4-D is not translocated from the leaves of plants kept for some time in a situation where photosynthesis cannot take place—for example, in an atmosphere free from carbon dioxide.

The importance of sugar in relation to translocation of growth substances is shown in a striking manner in Figure 2. It can be seen that whilst severe growth effects arise following the application of 2,4-D to the leaf of a broad bean plant grown in the light, the same treatment to the leaf of an etiolated plant which has been held in the dark to deplete its sugar reserves, produces no growth response. On the other hand, a similar etiolated plant whose treated leaf is cut at the tip and dipped into sugar solution is seen to produce a marked response. There is reason to believe that the movement of organo-phosphorus insecticides in plant tissues similarly follows the carbohydrate stream; though other factors are undoubtedly concerned in the distribution of such compounds within the plant (6). In this connection it is of interest to note that the movement of sugars themselves is facilitated by the presence of the borate ion.

Another important factor in relation to effective action of systemic compounds is their stability within the tissues of the plant. Under the influence of plant enzymes, such a compound may be broken down completely or converted to a derivative with quite different biological properties. The compound so formed may be inactive or even more active than the substance originally applied. Another possibility is that the presence of a systemic chemical in the plant might lead to the production of quite unrelated active compounds by an effect on the biochemistry of the host (3).

The systemic insecticides, sodium fluoroacetate and sodium selenate, and the systemic fungicide, griseofulvin, are thought to be fairly stable within the plant but with certain other compounds it is known that chemical changes occur. Thus, for example, the organo-phosphorus insecticides Systox and Metasystox are converted within the plant into other insecticidal compounds. Again, there is evidence that the nitrile and ester derivatives of certain phenoxy acids are hydrolysed to the active growth substances within the plant. The use of the two compounds γ-(2-methyl-4-chlorophenoxy) butyric acid (MCPB), and γ-(2,4-dichlorophenoxy) butyric acid (2,4-DB) for the control of weeds in certain legume crops also depends upon this principle. In these cases the butyric acids are themselves relatively harmless but are oxidised to the corresponding highly active acetic derivatives within the tissues of susceptible plants (7).

The possible use of systemic chemicals for the protection of plants against fungal diseases raises the question whether the natural immunity of plants towards many fungi is dependent on the presence of protective chemicals present within their tissues. Fungicidal substances have in fact been isolated from a number of plants. Several such compounds, of very high fungicidal activity, are present in the shoot and root tissue of broad bean seedlings (8). These substances, which are receiving intensive study in the writer's laboratory, may prove to be 'natural' systemic fungicides, though it must not be assumed that they will necessarily possess adequate stability to survive and move within the tissues of other plants and confer protection against diseases to which these are susceptible. Nevertheless, such investigations on naturally occurring fungicides provide a useful approach to the problems of systemic protection of plants against disease.

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CHEMICAL WEED CONTROL IN FORESTS

Control of unwanted vegetation presents practical problems in most managed forest areas of the world, the nature of weed growth being more diverse than in any other type of crop. The weed problems facing the forester range from growth of annual herbs and grasses in forest nursery crops to well established vegetation of perennial grass and herbaceous species, and unwanted shrubs and large trees in forest areas.

Forestry is much less intensive than most forms of crop production, so that difficult weed problems arise through the presence of a varied, and often well established, vegetation of perennial and woody species of little economic value. Such vegetation may obstruct reafforestation efforts, and compete for available light, water, and nutrient supplies with the desired natural or introduced timber producing species. If allowed to develop unchecked, vegetation competition may not only reduce timber yields but can also completely suppress the desired species, causing stagnation or death of the crop. In addition, uncontrolled vegetation may constitute a serious fire hazard to adjacent forest crops.

In the past, mechanical or time-consuming and costly manual cutting methods of clearance and weed control have been most commonly used. However, during the last 15 years, a number of chemicals have been developed and applied to forest weed control problems on a large scale, with considerable effect and saving in cost. In many countries, chemical weed control has been shown to have the advantages of speedy application, at a low cost and manpower requirement, compared with manual and many mechanical methods. The most notable disadvantages, which have held up practical development in some areas, have been lack of data on weed and crop susceptibilities, associated with the complexity and variation of weed types and species, the need for special equipment, the risk of herbicide drift on to neighbouring crops, and amenity considerations in some regions, especially when treatment of high woody growth is involved.

These problems are being overcome, and the scale of application of herbicides to forest weed problems has now attained large proportions, especially in North American, European and some tropical forest areas, where major economic gains have been achieved by the use of herbicides at five main stages of forest operations:

(1) Control of annual weeds in forest nurseries, where the use of mineral oils and residual herbicides, notably Simazine, has appreciably reduced weeding costs;
(2) Control of woody 'brush' and other vegetation in preparation for seeding or planting of cut-over, burned, or derelict land. Foliage, and/or stem and cut-stump treatments with growth-regulator type herbicides, are being applied on an increasing scale;
(3) Selective control of brush and herbaceous growth in newly regenerated areas, where growth regulators show considerable promise for weed control in young conifer crops;
(4) Release of planted or natural conifers from the competition of high cover of low-value hardwoods. Hardwoods have been selectively controlled by aerial spraying, or application of herbicides to the stems of weed trees in many countries;
(5) Control of vegetation encroaching on to uncropped areas, such as firebreaks, roads, fence-lines and power-lines. Here foliage spraying with growth regulators for control of brush is widespread, and residual herbicides have some application where persistent total weed control is required.

The total extent to which herbicides are applied at these stages throughout the world is difficult to assess. In terms of acreage, aerial application of foliage sprays for brush control is probably the greatest, and large areas are sprayed annually with 2,4,5-T or 2,4-D for release of conifers from hardwood competition in Canada and the United States. In the US some six million acres were sprayed from the air in 1958 for control of brush on forest and range land. In most European countries, notably Sweden, Norway, Germany, France, Belgium, Holland and the United Kingdom, herbicides are being used on an increasing scale, applied mainly with ground equipment and occasionally with aircraft, for control of weed growth and opening up of hardwood cover in the early stages of forest formation.

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For example, in Sweden, the use of 2,4-D and 2,4,5-T for control of brush in forest areas is almost as great as their use in agriculture. In tropical forests, the main use of herbicides so far has been for stem treatment of weed trees.

Forest weed problems and the herbicides which are currently used, or show promise, are best outlined in relation to the main weed types concerned, which can be broadly grouped into woody, herbaceous, and grass weed types.

Woody Weeds

The terms 'woody-weed' or 'brush' cover a wide range of species of shrub, climber, and tree growth, which may become weeds where they have no value, and impede development of the desirable forest crop. Most commonly, a woody-weed problem arises following exploitation or burning of forest, or abandonment of agricultural land, the sites being taken over by low-value hardwood scrub which prevents regeneration and growth of more productive species. Under other conditions, as in many tropical forests, the 'weeds' may consist of individual large trees of inferior timber quality, which need to be removed as cheaply as possible to favour more valuable species.

In most temperate-zone forests, the woody weeds are deciduous hardwoods, and the major use of herbicides is for control of hardwoods to enable seeding or planting of conifers, and to release existing conifer regeneration from suppression under the shade of overhead cover. This problem arises in many parts of the world, and herbicides have been used on a large scale to establish or release conifer crops, important examples being Douglas fir in North-west America, indigenous pine and spruce regeneration in the Great Lakes region, and the southern United States, and young spruce and pine crops in parts of Europe.

Herbicides are applied for control of woody growth in a variety of ways, including foliage sprays, basal stem and cut-stump treatments and, to a much lesser degree, application of soil-acting herbicides. These methods are extensively applied both in preparation of land for seeding or planting, and for weed control in planted areas. The choice of method is determined mainly by the height, density and nature of the weed cover, the susceptibility of the crop species, and the extent to which physical clearance of the weed growth is necessary.

For foliage spraying, the growth regulators 2,4-D or 2,4,5-T are by far the most widely used, and these herbicides have the virtues of being non-poisonous, non-corrosive, and effective against a wide range of species at relatively low rates compared with any other group of compounds. Low-volatile ester formulations of 2,4,5-T, or mixtures of 2,4,5-T and 2,4-D have been the most generally effective- and are commonly used as foliage sprays during the grow, ing season, when leaves are fully expanded and actively synthesising. The rates of application required vary, with species and spraying method, between 1 lb. and 4 lb. (acid), in spray volumes of 5 gal. to 150 gal. water or oil/water emulsion per acre.

Transport and application of large volumes of fluid can be serious problems due to the difficult terrain and access in many forest areas, and high-volume spraying is seldom practicable. For these reasons, aerial spraying with fixed-wing aircraft or helicopters is easily the cheapest method when the brush cover is thick, or high, or access is difficult. Aerial spraying at rates of 1-3 lb. 2,4,5-T (acid) in 1-5 gal. oil or oil/water emulsion per acre has given good results under many conditions. Spray drift can be a problem in some areas, and for this reason, coupled with amenity considerations, aerial spraying tends to be concentrated in the larger and less accessible forest areas.

For low brush (i.e., less than 4-5 ft. high) knapsack or powered ground-spraying equipment may be used, although high volumes of 50-100 gal. spray per acre are required for adequate leaf coverage. The development of knapsack-type and tractor mounted mist-blowers has been of special value for forest use, enabling uniform spray coverage to be obtained at rates as low as 10 gal. per acre, with consequent economy in transport and application costs.

The herbicides 2,4-D and 2,4,5-T break down in the soil within a few weeks and there is no evidence of important residual toxicity to trees planted after spraying. Also many conifers are relatively resistant to 2,4-D and 2,4,5-T at rates of 1-3 lb. (acid) per acre, if applied towards the end of the growing season, when conifer shoot elongation has ceased. This fact is enabling selective control of brush in young conifer areas to be obtained with considerable savings in costs compared with other methods.

In the search for more efficient herbicides for brush control, interesting results have been obtained with high viscosity invert emulsions of 2,4,5-T, which may be of value for reduction of the spray drift problem with low-volume aerial or mist-blower spraying. Work with other herbicides has shown promise on particular brush species with growth regulators such as 2,4,5-TP, aminotriazole, and trichlorobenzoic acid. However, for woody weeds as a whole, there are at present no serious contenders with 2,4,5-T and 2,4-D esters.

Control of weed trees and shrubs by application of herbicides to stem bases is extensively practised, particularly for opening up high brush cover where there are

Transplant lines of Douglas fir showing the effects of simazine on weed growth. The plot in the right rear of the picture was untreated; the left foreground plot received ½ lb. and the right foreground plot 2 lb. simazine active ingredient per acre.

Vigorous growth of coppice shoots from cut-stumps of hardwoods after clearance for planting can result in a costly weeding and cleaning problem. Here, treatment of chestnut stumps with 2,4,5-T ester at 1.5 per cent (acid) in diesel oil, immediately before planting Norway spruce, has given complete coppice control.

Bramble and other broadleaved weeds can suppress regeneration in woodland areas. These photographs (left, untreated; right, treated) *show the selective control of bramble in young Norway spruce following a late-summer spray with 2,4,5-T ester at 2 lb. (acid) in 10 gal. oil-water emulsion per acre.*

relatively few (less than 1,000-1,500) stems per acre, to be treated. Several techniques are in use, the choice depending mainly on species and size of stems. Thus, on stems less than 6 in. in diameter, low-pressure sprays may be applied to saturate the bark at the stem base and ground line, using an oil solution of 2,4,5-T ester at 1-2 per cent. (acid). This method has the advantage of being effective at any season on a wide range of species.

For larger stems, it is usually cheaper to apply the herbicides to notches, cups, or 'frill-girdles' cut near the stem bases. Herbicides that have been used in this way include sodium arsenite, ammonium sulphamate, amines and esters of 2,4,5-T, fenuron, monuron, sodium chlorate, TCA, DNBP and various toxic oils. At present, the commonest methods are the application of 2,4,5-T esters in oil to frill girdles, or ammonium sulphamate applied as dry crystals to stem notches. Coppice sprout development following the felling of many hardwoods can be a costly nuisance in regeneration areas, and 2,4,5-T esters in oil applied to saturate the bark of cut stumps has given good control of many species. Commonly, stumps of '2,4,5-T-resistant' species may be killed with ammonium sulphamate as dry crystals, or aqueous solution, applied to the cut surfaces.

Herbaceous Weeds

Brush control is of widespread forest importance, but in many situations growth of herbaceous weeds can also be a problem. In particular, rapid development of perennial herbs and grasses, which often follows the regeneration felling of forests, can seriously hinder the establishment and early growth of the new tree crop. Here again, herbicides have an important application. For perennial herbaceous species, 2,4-D and 2,4,5-T mixtures have been used before forest planting, and low-medium volume spraying shows promise for selective weed control in young conifers in the late summer, when conifer shoots have hardened off.

Grass Weeds

Perennial grasses are a difficult and widespread problem, and can compete seriously with young trees for water and nutrients, causing growth stagnation in extreme cases. Dalapon, applied as a foliage spray at 10-15 lb. (acid) per acre, a few weeks before planting in spring or autumn, has given good results, persisting for three to eighteen months according to the grass species concerned. Selective control of grasses in young tree crops is more difficult, as most trees are damaged by Dalapon reaching the foliage or roots during the growing season. However, directed inter-row sprays during the dormant period (late autumn to early spring) at rates not exceeding 8 lb. (acid) per acre, have given useful results. Other growth regulators, notably amino-triazole, and TCA have been used for grass control before planting in some countries.

Frequently, the forester is faced with a mixed weed problem of all the groups mentioned, and total herbicides such as paraquat, diquat, Dicryl and amino-triazole, or mixtures of 2,4-D, 2,4,5-T and Dalapon, can be of value, at least for the control of weeds before planting. Increasing attention is also now being given to the possible value of soil-acting herbicides applied before weeds develop, or to maintain the control achieved with growth regulator herbicides. For such use, residual herbicides, notably triazine and urea derivatives, and possibly seed toxins such as 2,6-DBN are of interest. Thus, 'spot' application of triazines in powder or granular form shows some possibilities for sustained weed control around individual tree positions. At an earlier stage, immediately after felling, non-persistent seed and bud toxins, such as 2,6-DBN, could be of value applied to the soil a few weeks before planting.

Herbicides have also been used extensively for weed control on uncropped land, including firebreaks, fence lines, power lines, etc., in forest areas, and 2,4-D and 2,4,5-T are applied on a large scale in such situations to control encroaching brush. Where complete control of the vegetation is required for fire protection and other purposes, soil sterilisation with borates, sodium chlorate, or triazine and urea compounds is carried out on a limited scale. This application is restricted to spots such as fence lines, steep ground and building surrounds, where mechanical cultivators cannot operate.

Space has not permitted more than the barest outline of the application of herbicides to the varied weed problems in forestry, and no reference has been made to individual major weed species. However, it should be clear that herbicides have already had a considerable impact on forest weed control practices, and the scope is increasing rapidly as new herbicides are developed. With rising labour costs, and the very large areas which may benefit from herbicide treatment, it is certain that the present rapid rate of development in this field will continue.

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Nitrogen requirements of forests

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The timber yield of cultivated forests is primarily dependent upon the nutrition of the trees. In Central Europe, for example, whereas a fertile site will yield an average of 15 cubic fathoms[1] of spruce *Derbholz* (i.e., wood having a diameter of down to 7 cm. at the thinner end) or 7-8 cubic fathoms of pine *Derbholz* yearly, a poorer site will yield barely half as much. On the poorest soils of all, the annual yield of timber will drop to less than 2 cubic fathoms.

This low yield is one of the reasons why the Federal Republic of Germany, in spite of the fact that 25 per cent. of its total area is wooded, cannot meet its own timber requirements. The forester is therefore understandably very anxious to discover the causes of these disturbances in growth, so that wherever possible he may take appropriate steps to remove them.

If growth is to be luxuriant, the soil must supply the trees with adequate quantities of at least 12 nutrients as well as with water, atmospheric oxygen and heat. The water, air and heat supply of a particular soil can be assessed from meteorological data, the condition of the soil and the distribution of the roots in it.

A considerable deficiency of nutrient substances causes deficiency symptoms affecting leaves and needles; these

[1] 1 cu. fathom = 216 cu. ft.

symptoms may denote a lack either of individual nutrients or of groups of them. The expert is able to distinguish a nitrogen deficiency from a potash, magnesium or phosphorus deficiency. It is generally easier to make a diagnosis on the basis of these deficiency symptoms in deciduous trees than in conifers, as the symptoms of potash and magnesium deficiency in the case of deciduous trees cannot be confused, whereas in the case of conifers, they are barely distinguishable. Deficiency symptoms only appear in cases of extreme deficiency; the absence of such symptoms therefore does not necessarily mean that the trees are receiving a plentiful supply of nutrients.

We know from the low yield of many forests that there are disturbances in the nutrition of the trees, although there are no recognisable symptoms of deficiency. In these cases a foliar analysis is a useful method of assessing the condition of the trees with regard to nutrition. This method is based on the observation that there is a close connection between the concentrations of nutrient elements in the leaves or needles, and the growth of the trees. In many regions, foliar analysis has helped to explain disturbances in the nutrition both of forest and fruit trees, and has been used in the testing of 68 pine stands and 69 spruce stands in Bavaria. The trial stands were growing on a variety of soils, so that a clear picture of the distribution of nutrient supplies was obtained. Most important of all was the discovery that the timber yield is clearly dependent upon the supply of nitrogen to the trees.

The needles of healthy pine stands which yield an average of over 5 cubic fathoms *Derbholz* yearly contain at least 1.5 per cent. N. This concentration was not reached in the weaker stands with less than 4.6 cubic metres' growth. Here one must not forget that the timber yield in stands which have an equally high N-concentration may differ considerably from one stand to another, since the yield of a stand cultivated under normal conditions depends not only upon the nitrogen supply but also upon whether all the other factors governing growth are favourable. There is a similar connection between the growth of spruce stands and their nitirgen content, although this relation is not so pronounced (correlation coefficient, R=O.595) because spruce trees are usually cultivated in richer soils, whilst the poorest sites are reserved for pines.

While the forests of Bavaria show evidence of widespread nitrogen deficiency, needle analysis has shown that there is not necessarily widespread phosphorus, potash, calcium or magnesium deficiency as well. The phosphorus deficiency noted in other regions, even in mineral soils, has so far been found only in peat soils in Bavaria. A potash deficiency occurs not only in peats, but also in sands with a very low potash content or in soils containing calcium carbonates.

Need for Nitrogen

Numerous fertilising tests have confirmed the results of needle analysis, which show that the forests' greatest need is for nitrogen. Evidently many soils do not provide the trees with the large quantities of mineral nitrogen which they require for good growth. Pine stands, if they are to be healthy, must absorb approximately 45 Kg N per ha. annually from the soil, whilst 30 Kg N per ha. is sufficient for only a moderate timber yield. The annual nitrogen requirement of spruce stands is even higher than this—i.e., approximately 60 Kg N per ha. or 40 Kg N per ha. These quantities seem small by comparison with the nitrogen requirements for agricultural purposes (about 100 Kg N per ha. will be required for high potato or wheat yields) but we must remember that agricultural cultivation can only produce quantities of nitrogen as large as these if intensive cultivation methods are used (e.g., abundant fertilisation with nitrogen), whereas the forests use the quantities of mineral nitrogen provided by the soils during the period of growth.

The annual quantity of mineral nitrogen supply is dependent upon the nitrogen content of the soils and upon the living conditions of the micro-organisms which mineralise the organic nitrogen compounds. Under conditions favourable to the forest, the micro-organisms provide the higher plants with up to 10 per cent. of the total nitrogen content of the soil in the form of ammonia or nitrate, by the mineralisation of organic nitrogen compounds.

In some raw humus sites containing pine stands, on the other hand, barely 1 per cent. of the total nitrogen supply is available to the trees. In raw humus areas, the average annual rate of nitrogen mineralisation depends to a large extent upon the nitrogen content of the organic matter in the soil. Raw humus top-soils which are rich in nitrogen, containing about 2 per cent. N in the organic matter, supply more mineral nitrogen than those containing less than 1.5 per cent. Understandably, the higher the rate of nitrogen mineralisation and the higher the nitrogen content of the soil, the more nitrogen is there available to the trees. Fertile spruce stands in Bavaria contain, on average, 1,024 Kg N per ha. in their top-soils; the mineralisation rate of 7.6 per cent. gives an annual supply of mineral nitrogen from the soil of 78 Kg N. The corresponding pine stands contain about 500 Kg N, from which, with a mineralisation rate of about 5 per cent., an average of 25 Kg N per ha. is supplied in the period of growth. The best forest areas tested in Bavaria provide 130 Kg mineral nitrogen, and the worst only a few kilograms.

Improving Nitrogen Supply

Raising the rate of mineralisation by activating the nitrogen reserves of the soils, increasing these reserves, and adding mineral nitrogen which can be assimilated by plants as a fertiliser, all hold some promise of success as means of improving the supply of nitrogen to trees.

Raw humus top-soils, with a low average annual rate of mineralisation, accumulate on soils which do not provide animals and micro-organisms with favourable living conditions. In Bavaria, the bases contained in such soils are negligible and the litter is often formed exclusively by needles. In many forest areas, therefore, an increase in the numbers of animals and micro-organisms is observed after a treatment with lime, or after some deciduous trees have been introduced into a conifer stand, and this leads to a conversion of the raw humus into something approaching

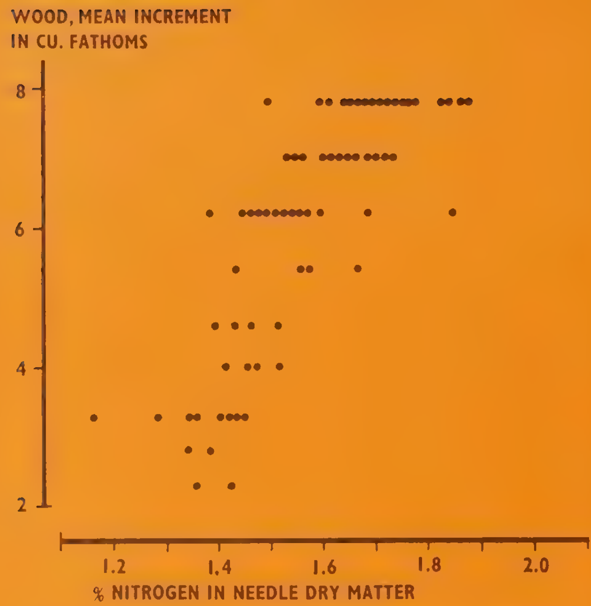

Fig. 1. This figure illustrates the dependence of timber yield in pine stands upon the nitrogen content of the needles (correlation coefficient, R = 0.853).

Symptoms of nitrogen deficiency in pine needles (left) compared with healthy needles.

moss humus. This conversion is highly desirable, because by contrast with the majority of raw humus sites, the pine and spruce stands on all mull humus sites and on the majority of moss sites are adequately supplied with nitrogen.

On sites where the raw humus top-soils are particularly deficient in nitrogen and phosphorus, the activation of raw humus can only take place after combined fertilisation with lime, phosphorus and nitrogen. The additional nitrogen application also prevents the formation of a biological nitrogen barrier (after treatment with lime) which would increase the nitrogen deficiency of the trees at least for some time.

Nitrogen Intake and Loss

The nitrogen content of the soil is dependent upon the nitrogen intake and loss, and can therefore be increased by reducing the losses, by increasing the intake, or by doing both at the same time.

On the intake side, it is possible to measure the quantities of nitrogen which find their way into the soil yearly with the rainfall. In central Europe, the precipitation contains 3-7 Kg N in the form of ammonia or nitrate. Losses by leaching, which can be assessed on the basis of a few measurements, are about 2-4 Kg N per ha., and are chiefly dependent upon the supply of mineral nitrogen in the soil, the mineral nitrogen consumption through plant growth, the quantity and distribution of the precipitation, and the exchange capacity of the soil. If in spring, before trees begin to absorb nutrients, the soil is warmed as a a result of a sudden warm spell, and this is immediately followed by heavy rainfall, there will be heavy losses by leaching in soils with a low exchange capacity.

More is known about the quantities of nitrogen which are removed from the forest with the timber. In central Europe, the annual timber yield contains about 10 Kg N per ha. without the bark. If brushwood, bark and even a part of the roots were harvested in addition to the *Derbholz*, the nitrogen resources of the soil would be drained still further and an average of about 20 Kg N per ha. would be removed from it yearly.

Precipitation provides a measurable intake of only 3-7 Kg N to offset the nitrogen losses through forestry and leaching at the rate of 12-24 Kg ha. In addition to this, there will probably be a certain intake of nitrogen through the absorption of ammonia in the course of an exchange of gases between the atmosphere and the soil. It has been established that 4-7 Kg N per ha. penetrate into the soil in this way every year, and a considerable increase in the nitrogen content may be achieved in well ventilated, acid forest soils near large towns or industrial centres.

It is not possible to achieve a credit balance of nitrogen in cultivated forests on the basis of the intakes and losses described. Nitrogen losses in the form of gases escaping from the soil, which must also be taken into account, may in fact tip the scales on the debit side. For this reason, the intakes of nitrogen by nitrogen-fixing micro-organisms are of the utmost importance to the nitrogen supply of the soil, and therefore to the yield of the forest. The forester makes use of these nitrogen-fixing micro-organisms by cultivating beneficial species of plants which live in symbiosis with them. The cultivation of *Lupinus perennis*, *Sarothamnus scoparius* and *Alnus* (alder) has met with considerable success. We do not yet know whether it also succeeds in stimulating to greater activity the free-living, nitrogen-fixing micro-organisms in the forest soil.

It will probably be easier to use these inexpensive sources of nitrogen when we know more about the requirements of nitrogen-fixing organisms in the forest soil. Many tests carried out all over the world indicate that nitrogen fixation may be of immense value if the soils are not highly acidic, if they contain sufficient phosphorus, molybdenum and an abundance of readily decomposable energy-giving material deficient in nitrogen, and if they also contain a certain

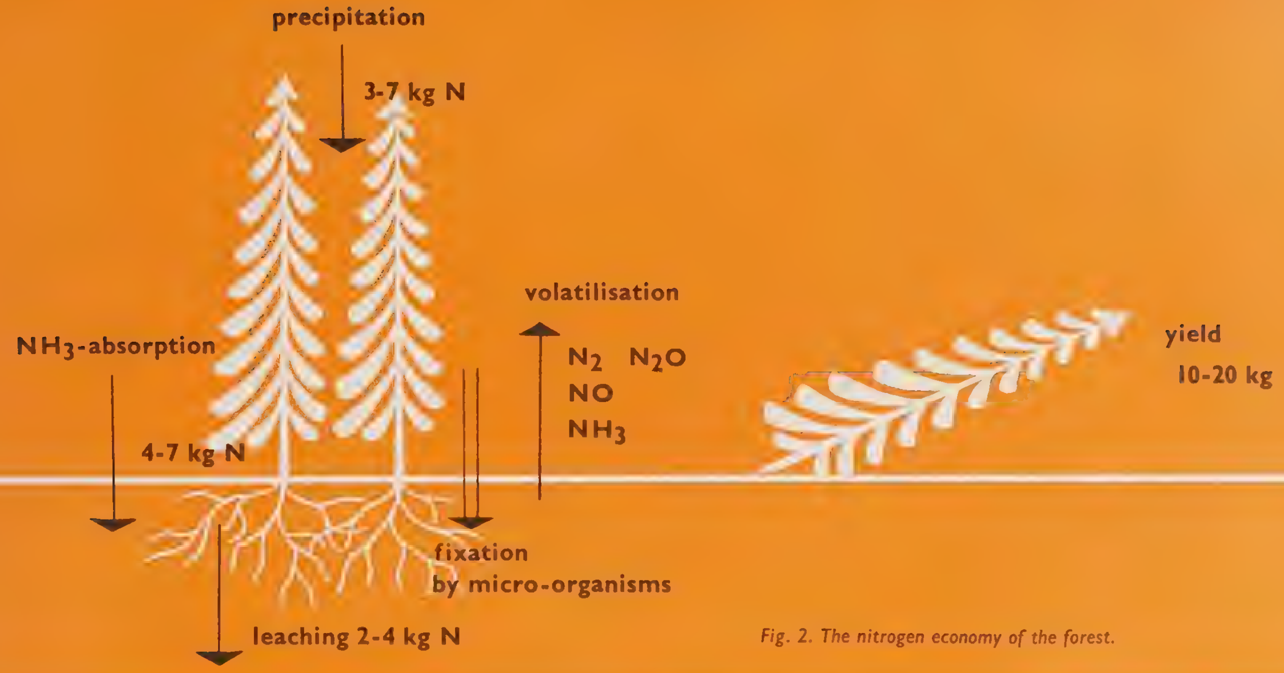

Fig. 2. The nitrogen economy of the forest.

amount of clay, and the requisite supply of water. It may be possible to obtain better conditions for the nitrogen-fixing micro-organisms by methods which bring about the conversion of raw humus top soils.

However, even where conditions are most favourable, the nitrogen-fixing micro-organisms will not be able quickly to offset the heavy nitrogen losses suffered by many forests in Bavaria as a result of the removal of the organic raw humus layer. The entire raw humus top soil, including the undergrowth, is often removed several times in the lifetime of a stand, and taken off to be spread in cow byres. Nitrogen losses resulting from a single removal of the organic layer are sufficient to jeopardise the nitrogen supply of the trees for decades.

Fertiliser Use

It is only after fairly long periods that success can be obtained on many stands with the methods described. Nitrogen fertilisers are more suitable for short-term improvement of the nitrogen supply: in trials they have not only promoted the growth of the trees, when correctly used; they have also produced an economic gain.

The prerequisite for the successful use of fertiliser is in every case the correct diagnosis of the disturbance in the nutrient supply; foliar analysis is an excellent method for this, and is also very suitable for assessing the effect of the fertiliser. Only by means of this analysis can we determine whether and to what degree the fertilisers are absorbed by the trees, and whether we have succeeded in increasing the concentration of nitrogen in the leaves.

Since the stands generally absorb 30-60 Kg N during a single period of growth, and since the soil itself provides a portion of this, it is not necessary for the annual dose to exceed 100 Kg N. Even in this quantity the dose should, where possible, be split into two doses, one at the beginning of the period of growth and one four to six weeks later. If the nitrogen concentration in the needles fails to increase to the desired extent, fertilisation must be repeated in succeeding years. In later years, further fertilisation will be indispensable, because the effect of fertilisers gradually falls off. The time at which refertilisation should take place can be determined by a foliar analysis.

In forest areas where there is a nitrogen deficiency, any measures for improving the nitrogen supply will result not only in more abundant growth, but also in an increase in the resistance of the trees to attack by fungi and pests, and in this way they will contribute to the healthy condition of the forests.

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Fig. 1. A six-outlet gravity flow injector. The fumigant flows from the tank, in which a constant head is maintained, through a distributor boom, and thence via metering units to outlet tubes attached to cultivator tines. Note the roller for sealing the soil after injection.

Techniques and equipment for soil fumigation

by **L. S. Cathie,** *Shell International Chemical Company.*

Plant parasitic nematode control by soil fumigation, using volatile liquid nematicides, is a rapidly expanding form of crop protection, which can yield handsome dividends in areas where nematodes are a limiting factor in high value crop production.

To be fully effective, volatile soil fumigants, such as D-D (1,2-dichloropropane, 1,3-dichloropropene mixture) and Nemagon[1] (1,2-dibromo-3-chloropropane), have to be placed at a depth of 6-8 in. in well-tilled soil, which has been brought as near to seed-bed condition as possible. If a phytotoxic fumigant like D-D is used, land must be treated and the fumigant allowed to disperse before planting takes place. Nemagon, however, is non-toxic to many plants at nematicidal concentrations, and can be used to treat a large number of crops either at planting time or once they are established.

This article briefly describes some of the techniques and equipment developed to apply D-D and Nemagon.

Small-Scale Application

On a small scale, and sometimes on a larger scale in areas where labour costs are low, land may be fumigated using hand-operated injectors. Most of these injectors work on the same simple principle, in which a piston is depressed to eject from a reservoir tank a fixed amount of liquid, previously determined by calibration, through a hollow spike inserted to the required depth in the soil. Figure 2 shows a typical hand injector.

Even if hand ejectors are not available, it is still quite possible to fumigate small areas successfully by making 6 in. deep furrows and pouring fumigant along the bottoms, using any receptacle which will enable the operator to apply approximately the right amount of fumigant. In Holland, for example, a watering-can with all but three of the holes in the rose blocked up has been found suitable for this purpose. An ordinary tin can may even be adequate. Another very simple method of application is to make holes 12 in. apart in the soil and pour fumigant into them from a bottle fitted with a measuring device.

When using volatile soil fumigants, it is important that the furrows or holes should be filled in and the earth lightly stamped down as quickly as possible after application, to prevent loss by volatilisation.

Large-Scale Application

Where large areas are being treated, except where labour costs are very low, it is essential to employ tractor- or horse-drawn equipment, and several injectors have been developed for this purpose. The majority operate on one of two principles—gravity-flow or pressure injection. The

[1] Nemagon is a Shell trade mark

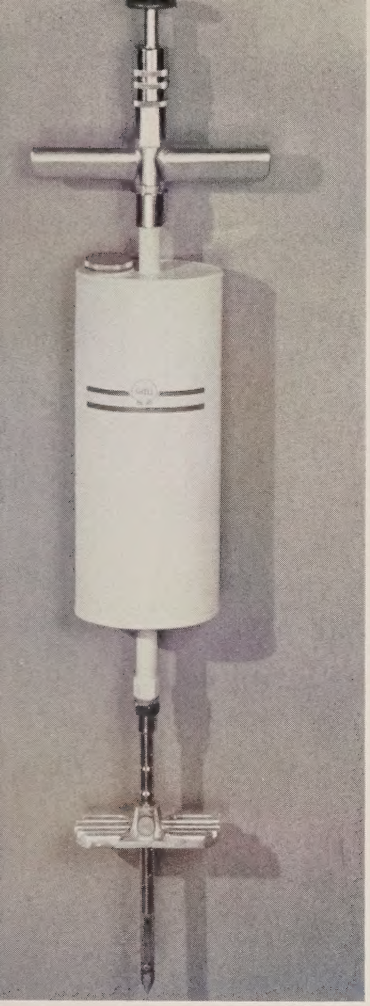


Fig. 2. This hand-operated soil fumigant injector incorporates a dosage regulator which allows the injector to be set to deliver any quantity of fumigant from 1 cc to 10 cc at each piston stroke.

Fig. 3. A gravity flow injector attached to a two-way plough. Here the fumigant flows through a drip tube into the open furrow where it is immediately covered by soil turned by the share.

simplest and cheapest are those in which the fumigant flows under gravity from a tank in which a constant head of liquid is maintained, through a distribution boom and thence via metering units to outlet tubes which are usually attached to the back of cultivator tines. Figure 1 shows a typical gravity-flow injector. This particular model is available in the form of a kit of parts to be assembled by the user; it can be attached either to a toolbar or to a plough (Figure 3). With this type of equipment it is essential to ensure that air can enter only through the air-inlet tube attached to the reservoir, otherwise a constant head cannot be established and the dosage rate will vary.

The rate of flow of liquid to each tine in gravity-flow injectors is governed by a metering unit such as a calibrated needle valve, or, as in Figure 1, a coiled length of copper tube. The flow rate of liquid through this tube will depend on the head and viscosity of the liquid, and on the length and diameter of the tubing. With this kind of metering equipment, therefore, a series of inter-changeable coils is all that is necessary to give a range of dosages for any given fumigant.

When using most gravity-flow injectors it is necessary to keep the speed of the tractor constant, or there will be variations in the dosage applied. However, this drawback has been overcome in a gravity-flow injector, developed at the University of Ghent, in Belgium, and now in commercial production, in which the application mechanism is linked with the turning of the wheels (Figure 4).

The other type of machine in common use—the pressure injector—is operated by a pump driven by the power take-off of the tractor. The main advantage of this type of injector is that dosage is independent of speed over the ground, as the pump pressure can be altered to compensate for changes in speed. As a rule pressure injection equipment is more expensive than gravity-flow, and is therefore mainly used by contractors and growers who have large areas to fumigate.

When applying soil fumigants with a horse- or tractor-drawn injector, the soil surface is best sealed after injection by drawing a roller or heavy drag behind the injector.

Special Techniques

Nemagon soil fumigant is available as an emulsifiable concentrate and as granules, in addition to the unformulated product.

Emulsifiable Concentrate. Nemagon emulsifiable concentrate diluted with water can be applied by any of the methods described above. In addition, an application technique which is gaining in popularity, for both pre-planting

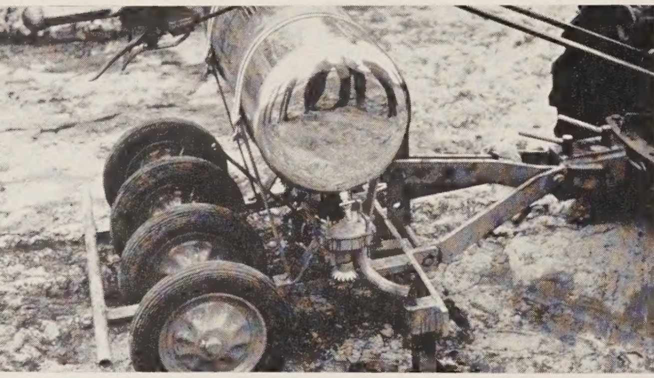
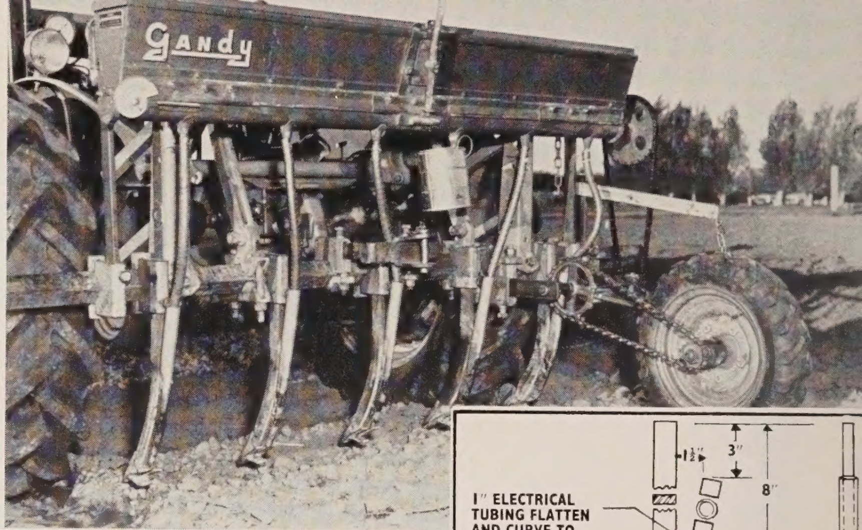


Fig. 4. The Ghent Fumigator, a gravity flow injector in which the application mechanism is linked with the turning of the wheels, so avoiding the need to maintain a constant speed while fumigating.



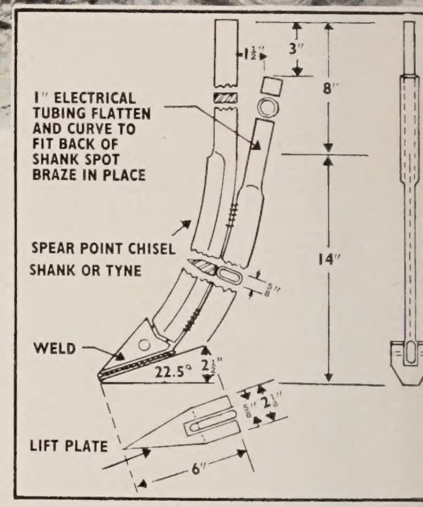


Fig. 5. A distributor adapted for applying Nemagon granules at six-inch depth. Inset: a suitable type of tine for placing the granules at this depth.

and post-planting treatments, is the incorporation of the emulsifiable concentrate in irrigation water. This is especially valuable in the case of perennial crops because by this method it is possible to place the Nemagon in intimate contact with plant roots without injuring them.

The best results have been obtained with flood and basin irrigation, using large volumes of water, and introducing the chemical, thoroughly mixed with water, over the entire period of irrigation. Adequate mixing is best achieved by metering the emulsifiable concentrate through a centrifugal pump or, more simply, by introducing it at a point where there is sufficient turbulence in the water.

Baines *et al.* (1) found that Nemagon effectively controlled citrus nematode in a number of citrus orchards, and increased fruit yields, when the chemical was applied either by injection or in irrigation water 5-6 in. deep in basins. However, when the chemical was applied by furrow and sprinkler irrigation in a number of tests, control of the citrus nematode was much poorer. McBeth (3) also reports that in comparative tests results with furrow irrigation have not been equal to those obtained from flood irrigation. He states that in a flood irrigation experiment using Nemagon emulsifiable concentrate, carried out in a navel orange grove in Arizona, USA, the degree of nematode control 13 months after treatment was still 99.9 per cent., and the yield increase of treated over untreated areas was approximately 40 boxes per acre.

Granules. Good and Steele (2) found that granular formulations of 1,2-dibromo-3-chloropropane gave adequate control of root-knot nematode provided the chemical was placed 6 in. or more below the soil surface. Many granular insecticide, fertiliser and seed drills which are designed to place material just below the soil surface can be converted for applying Nemagon granules at 6-8 in. depth by using a special tine (Figure 5). A suitably adapted applicator is shown in Figure 5. Nemagon granules have also been successfully applied by broadcasting them on the soil surface and ploughing in immediately after spreading (3).

In contrast, little success has been achieved by applying the granules to the soil surface and working them in with a disc harrow—probably because it is not possible to get sufficient Nemagon down to the required depth using this method.

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Weeds and Aliens. Sir Edward Salisbury. Collins, London. 30s.

A recent symposium on the biology of weeds was introduced with the observation that 'Weeds have for many years been regarded as slightly improper material for biological studies. . . .' Fortunately, not everyone has regarded weeds in this light, and of those who have found weed biology a fascinating field for study, Sir Edward Salisbury is outstanding. He confesses to an interest in weeds extending over 50 years, and during this time he has observed, grown, measured and experimented with a very large number of species. In addition, he has made a practice of extracting relevant data from the literature.

At a time when there is an upsurge of interest in the biological characteristics of weeds as well as in their control, it is fitting that Sir Edward's accumulated knowledge and experience should reach a wider public than hitherto, and author, editors and publisher are to be warmly congratulated on this latest 'New Naturalist'. The high standard of production of the series is well known, and this volume is no exception. It is illustrated by the author's own diagrams, drawings and photographs and there are also some magnificent full-page black-and-white plates by John Markham.

It is no exaggeration to state that the text is packed with facts, figures and pertinent observations. Here can be found information on the history of weeds in Britain, their habitats and spread, and data on seed output, dispersal, viability, dormancy and germination. Although not intended to provide descriptions of species, many useful points of recognition are mentioned which help greatly in making the plants 'come alive'. As the title indicates, weed aliens, such as those deriving from the use of shoddy as manure, are fully treated, and there is an especially interesting chapter in which those species that have become nuisances after escaping from gardens are tabulated and discussed. Throughout the text, Sir Edward's enthusiasm for his subject is apparent and the enormous amounts of information which he has himself obtained is combined with data from many other sources. There are a few minor errors, including a reversal of legends in Plate I, two aberrant figures on page 327 and some variation in the spelling of authors' names.

The question of how far to include consideration of chemical control methods must have been a difficult one to resolve. In fact, brief indications of susceptibility to herbicides, mainly MCPA and 2,4-D, are given in the accounts of individual species. Although rates of application are often mentioned, it is doubtful whether they are of much value by themselves, since choice of chemical and dosage depends at least as much on the crop as on the weed.

The final chapter is also devoted to herbicides. It is proper that they should be considered, as their widespread use is likely to have far-reaching effects on our weed flora. Indeed, one could wish that the author might have expounded more fully on their ecological implications. Obviously, however, in a short chapter the treatment of the rapidly-developing subject of chemical weed control can only be fragmentary, though one feels that the choice of detail selected for inclusion has not been wholly felicitous. The impression is given, for example, that DNOC-ammonium serves as an alternative to sulphuric acid for pre-emergence use on onions and beetroot, while the mention of proprietary brand names for herbicides could have the effect of 'dating' the book, which would be a pity.

These comments concern only a small part of the book. As a whole, it deserves nothing but praise, and a wide variety of readers, including botanists, teachers, students and gardeners will be indebted to the author for providing such comprehensive information in such accessible form. It will certainly go a long way towards fostering the aim of the New Naturalist series in recapturing the inquiring spirit of the old naturalists, and will make many people more conscious of the interest to be found in those plants which grow nearest to their own doorsteps.

H. A. Roberts.

Bacterial Plant Pathogens. C. Stapp. Oxford University Press, London. 42s.

Within three years following the publication of *Pflanzen pathogene Bakterien* by Dr. C. Stapp, the Oxford University Press have published an English edition, translated by A. Schoenfeld. This handbook covers part of the field of plant pathogenic bacteria described by the same author in Sorauer's *Manual of Plant Diseases* (2nd Ed. 1956). The general part deals with a very useful and comprehensive description of bacteriological techniques, methods of identification of plant pathogens including staining techniques, biochemical tests and serological methods.

The special part is devoted to a description of 24 bacteria species such as *Agrobacterium tumefaciens*, several *Corynebacterium*, *Erwinia*, *Pseudomonas* and *Xanthomonas* species.

For each species a description is given of the pathogen, the disease symptoms, mode of infection, the spreading of bacteria in the host plants, resistant plant species, geographical distribution, and in addition some control measures for the diseases are indicated; the relevant literature references are given in detail. The book contains an excellent index and is well illustrated.

The bacteria covered by Stapp are limited to those prevalent on Central European plants. Unfortunately, the bacterial diseases of important tropical crops are not mentioned.

The literature is extensively covered up to 1953; recent literature up to 1957 is mentioned more sporadically. As Dr. Stapp considers the bacteriophages of only limited importance for the identification of bacteria, only half a page has been devoted to this subject.

Synonyms are not given and discussions on nomenclature are kept to a minimum.

The high standard of the contents of the book will fully compensate for the occasional shortcomings in the English translation. The fact that a general chapter on bacteriological techniques is included will widen the circle of readers to include students as well as others entering the field of bacteriology. We hope they will soon agree with the motto of the book: *In minimis deus maximus.*

J. Th. W. Montagne.

Span

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